The Earth Observing System Educators' Visual Materials

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Section 6. Self-Explanatory Auxiliary Slide Set *(PDF - 4 MB)*

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The Earth Observing System Educators' Visual Materials

Earth Sciences Directorate
NASA/Goddard Space Flight Center, Greenbelt, MD 20771

From its origins, the Earth has experienced change. It is a natural process. However, there are strong scientific indications that natural change is being accelerated by human intervention. We have altered the Earth by reconfiguring the landscape, by changing the composition of the global atmosphere, and by stressing the biosphere in countless ways. In our quest for improved quality of life, we have become a force for change on the planet, building upon, reshaping, and modifying nature-often in unintended ways.

As a result, planet Earth faces the possibility of rapid environmental change, including climate warming, rising sea level, deforestation, desertification, ozone depletion, acid rain, and reduction in biodiversity. Such changes would have a profound impact on all nations. However, we do not fully understand either the short-term effects of our activities or their long-term implications - many important scientific questions remain unanswered. For example, while most scientists agree that global warming is likely, its magnitude and timing (especially at the regional level) are quite uncertain. Additional information on the rate, causes, and effects of global change is essential to developing the understanding needed to cope with it.

The National Aeronautics and Space Administration (NASA) is working with the national and international scientific communities to establish a sound scientific basis for addressing these critical issues through research efforts coordinated under the U.S. Global Change Research Program (USGCRP), the International Geosphere-Biosphere Program (IGBP), and the World Climate Research Program (WCRP).

Mission to Planet Earth (MTPE) is NASA's contribution to the U.S. Global Change Research Program. It will use space- and ground-based measurement systems to provide the scientific basis for understanding global change. The space-based components of MTPE will provide a constellation of satellites to monitor the Earth from space. A major component of Mission to Planet Earth is the Earth Observing System (EOS). EOS will provide sustained space-based observations that will allow researchers to monitor climate variables over time to determine trends; however, space-based monitoring alone is not sufficient. A comprehensive data and information system, a community of scientists performing research with the data acquired, and extensive ground and airborne campaigns are all important components of the EOS program. But, more than any factor, NASA's commitment to make Earth science data easily available to the research community is the critical key to EOS mission success. Only through research can scientists advance knowledge of climate change, providing guidance to policy makers and the public who must balance social and economic concerns with the welfare of the planet and the species that inhabit it.

Developing an understanding of how our home planet, Earth, functions in response to interactions among land, oceans, and atmosphere has presented a critical challenge that must be met if we are to predict the impacts of human activities on local, regional, and global climate change. The Earth system science concept promotes the study of Earth as an integrated system of atmosphere, ocean, and land, while bridging the traditional disciplines of physics, chemistry, and biology. The field of Earth science has matured from the point of understanding processes in ocean, land, and atmosphere components treated separately to studying their connections at global scales.

The EOS constellation of satellites will acquire global data, beginning in 1998 and extending well into the twenty-first century. The overall objective of the EOS program is to develop the ability to predict environmental changes that occur both naturally and as a result of human activities. To process and analyze the vast quantities of data acquired by EOS over an extended period of time, and, ultimately, to achieve the objective of the EOS program, presents a formidable challenge to develop a new body of scientists and engineers to come into the program as the years pass. The only way to meet this challenge is through the teaching of Earth system science in the schools, colleges, and universities. There is a need for preparing students and researchers at all levels‹kindergarten through twelfth grade, undergraduate, graduate, and postgraduate.

The purpose of this slide package is to help educators and researchers gain access to the most-recent space-based observations NASA has obtained regarding Earth system science. NASA hopes that this package proves useful and plans periodically to update this set as additional observational and analytical data become available as part of its MTPE Program.

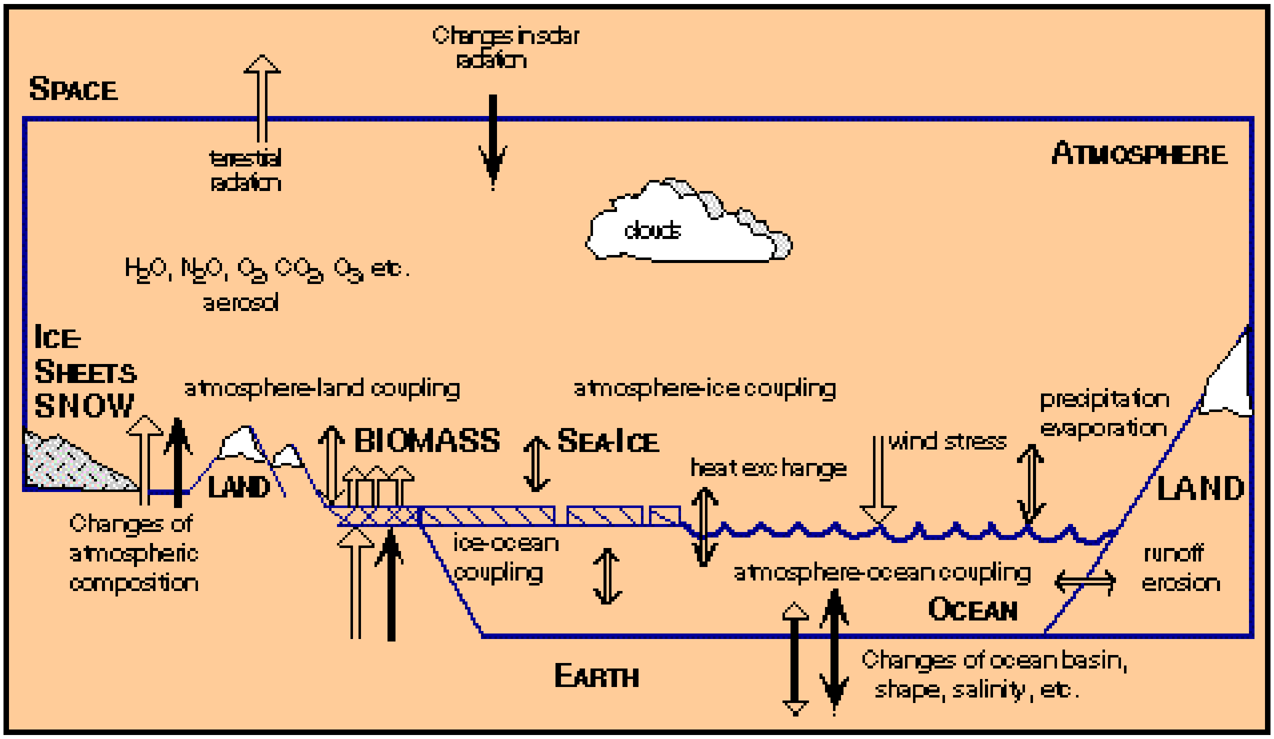
Addressed in Section 2 of this educational package are seven Earth science themes that Earth scientists consider of primary importance: Clouds and Radiation; Ocean Productivity, Circulation and Air-Sea Exchange; Greenhouse Gases; Changes in Land Use, Land Cover, Primary Productivity, and the Water Cycle; The Role of Polar Ice Sheets and Sea Level; Ozone Depletion; and The Role of Volcanoes in Climate Change. Each of these themes is illustrated in the first set of slides found in Appendix A.

Section 3 contains a series of NASA Fact Sheets on related topics. Accompanying 35-mm slides of the descriptive charts contained in the Fact Sheets can be found in Appendix A.

Sections 4 and 5 contain a glossary, a list of acronyms and abbreviations, and general information for teachers and students.

Appendix B contains a supplementary set of slides that provides a further perspective on the same seven broad theme areas as covered in Section 2.

These are but samples of data that will be provided to scientists worldwide continuously for at least 15 years by the Earth Observing System, providing the basis for the most extensive research program ever undertaken to study this planet, our home, the EARTH.



The many interactions in the "coupled" Earth system. The full arrows are examples of external processes, and the open arrows are examples of the internal processes in climate change [after Houghton, J.T. (ed.), 1984: *The Global Climate;* Cambridge University Press, UK, 233 pp].

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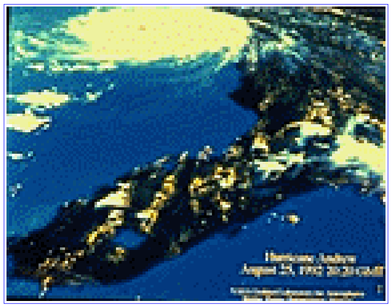
ID: 1-01

Hurricane Andrew



Hurricane Andrew, August 25, 1992 20:20 GMT

A hurricane is one of nature's most awesome phenomena. Called typhoons when they originate in the western Pacific, they are low-pressure weather systems characterized by strong winds blowing in a circular pattern about a central core. The central core, also known as the "eye" of the hurricane, is remarkably calm in contrast to the surrounding winds. As a hurricane passes over a certain location, people in the area witness violent winds and rains, followed by a period of calm as the eye passes over them. Once the eye has passed over, the raging winds and heavy rains again thrash the land.

Hurricanes are assigned names by the national and international weather services. By definition, they contain winds in excess of 74 miles per hour (119 km per hour) and large areas of rainfall. In addition, they have the potential to spawn dangerous tornadoes. The strong winds and excessive rainfall also can produce abnormal rises in sea levels and flooding.

This image [constructed using data from the Advanced Very High Resolution Radiometer (AVHRR) on a NOAA satellite] highlights some of the interesting features of a typical hurricane as it is viewed from space. It shows Hurricane Andrew approaching the Gulf Coast of the United States. Notice the clear eye of the hurricane and the spiral rain bands, which are characteristic of all hurricanes.

Research leading to an increased understanding of these awesome storms will be performed using data from a Precipitation Radar and other remote-sensing instruments scheduled for flight on the Tropical Rainfall Measuring Mission (TRMM) and the Moderate-Resolution Imaging Spectro-radiometer (MODIS) and other instruments scheduled for flight on the EOS satellites.

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Hurricane Andrew
August 25, 1992 20:20 GMT
NASA Goddard Laboratory for Atmospheres

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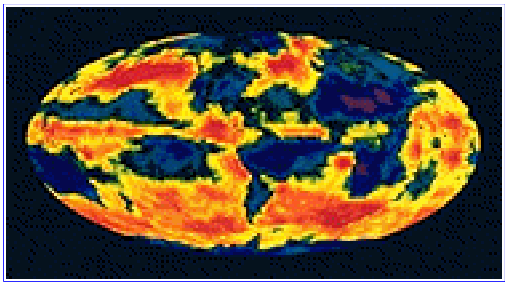
ID: 1-02

Percent Average Cloud Cover, May 1987



Percent Average Cloud Cover, May 1987

When looking at Earth from space, one of the most distinct features we see is its cloud cover. Clouds are visible aggregates of water droplets, ice particles, or a mixture of both that occur in the atmosphere above the Earth's surface.

This image from the High Resolution Infrared Radiation Sounder (HIRS)-2/Mirowave Sounding Unit (MSU) on the NOAA-10 satellite represents the average amount and global distribution of cloud cover during May 1987. Clear-to-mostly-sunny skies are shown in purple and dark blue, increasing cloud cover in lighter shades of blue and green, and mostly-cloudy-to-completely-cloudy skies in yellow, orange, and red.

Clouds play an important role in the Earth's climate system by affecting the amount of heat--in the form of electromagnetic radiation--that is allowed to pass into or out of the system. The balance between radiation coming to the Earth from the sun and the radiation emitted and reflected from the Earth system is known as the Earth's radiation budget.

Generally speaking, low, thick clouds tend to cool the Earth by reflecting the sun's radiation and preventing it from reaching the Earth's surface. In contrast, high, thin clouds tend to warm the planet by allowing solar radiation to pass easily through to the Earth's surface while, at the same time, trapping some of the Earth's infrared radiation and radiating it back to the surface.

Whether a given cloud will cause heating or cooling depends on several factors, such as the cloudÕs height, its size, and the make-up of the particles that form the cloud. The balance between the cooling and warming actions of global cloud cover is very close although, overall, cloud cover produces cooling on a global basis.

Research on global cloud cover and cloud properties will be performed using data from the Clouds and the Earth's Radiant Energy System (CERES) instrument scheduled for flight on the Tropical Rainfall Measuring Mission (TRMM) and on the EOS satellites.

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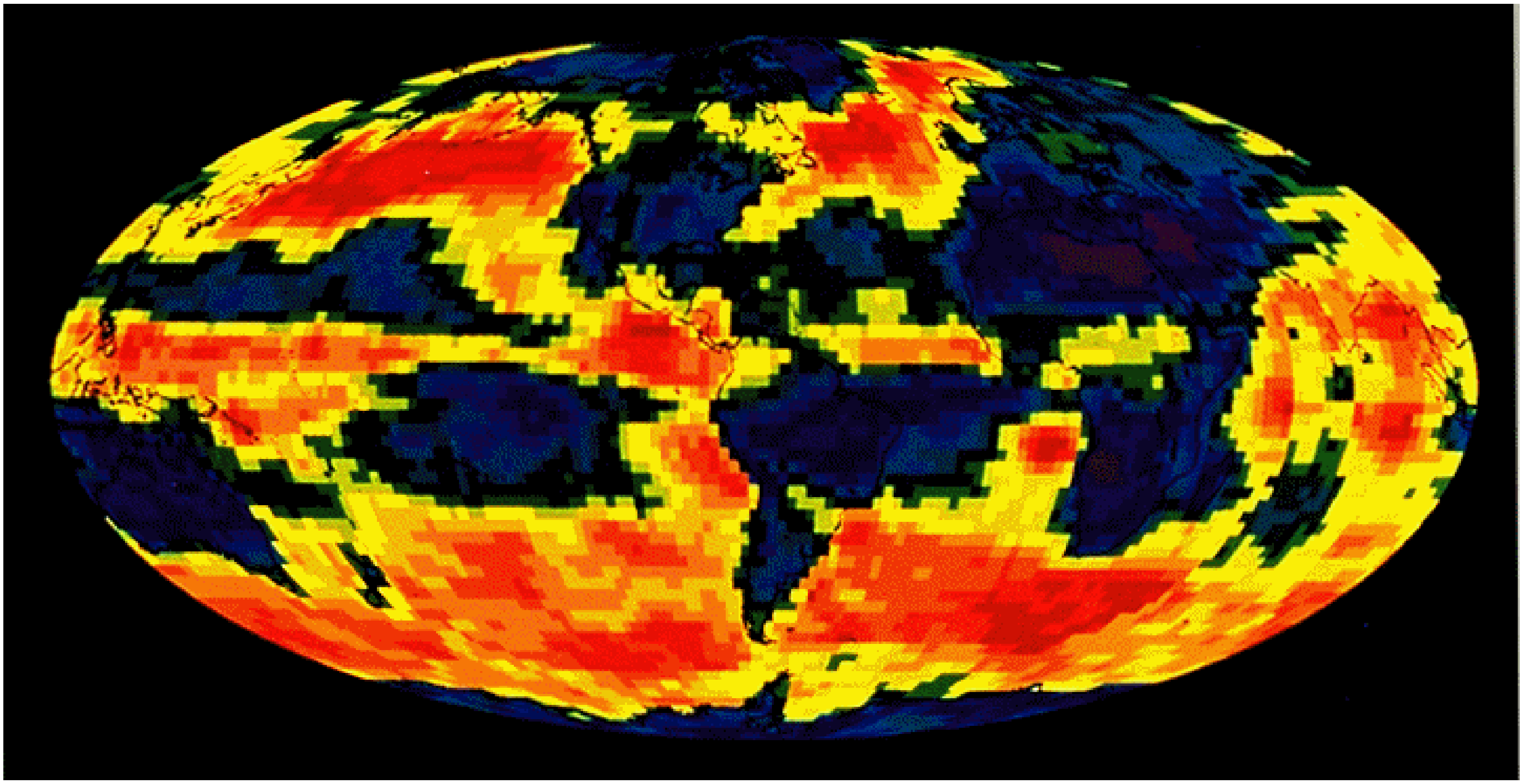
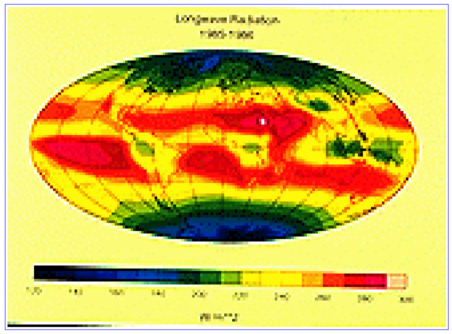


The Earth Observing System Educators' Visual Materials

ID: 1-03

Outgoing Longwave Radiation, 1985-1986



Longwave Radiation, 1985-1986

This image represents the average amount and distribution of heat--in the form of longwave electromagnetic radiation--that was radiated from Earth to space by the Earth's climate system in the period, 1985-1986, as measured by the NASA Earth Radiation Budget Experiment (ERBE) instruments on the Earth Radiation Budget Satellite (ERBS) and the NOAA-9 satellite. Areas in the purple-to-blue range indicate smaller amounts of outgoing longwave radiation (OLR); areas in the light-blue-to-red range indicate greater amounts of longwave radiation leaving the Earth.

Energy emitted by the Earth's climate system tends to maintain a balance with solar energy coming into the system. This balance, known as the radiation budget, allows the Earth to maintain the moderate temperature range essential for life as we know it.

When incoming shortwave solar radiation, known as insolation, enters the Earth's climate system, a portion of it is absorbed at the Earth's surface, causing the surface to heat up. Some of the absorbed energy is then radiated outward in the form of longwave infrared radiation. Cloud layers trap some of the radiation from the Earth's surface, and then emit longwave radiation, both outward and back to the surface.

The amount of radiation emitted by the Earth's surface that makes it back to space is the result of many interrelated influences, such as the amount of cloud cover, cloud heights, characteristics of cloud droplets, amount and distribution of water vapor and other greenhouse gases, land features, surface temperature, and the transparency of the atmosphere.

In the warm tropical areas, low values of OLR correspond to large amounts of high, cold clouds while high values of OLR correspond to relatively clear areas or cloudy areas with low, warm clouds. In the extra-tropics OLR values typically decrease with decreasing temperature.

Continuing research on the Earth's radiation budget will be performed using data from the Clouds and the Earth's Radiant Energy System (CERES) instrument scheduled for flight on the Tropical Rainfall measuring Mission (TRMM) and on the EOS satellites.

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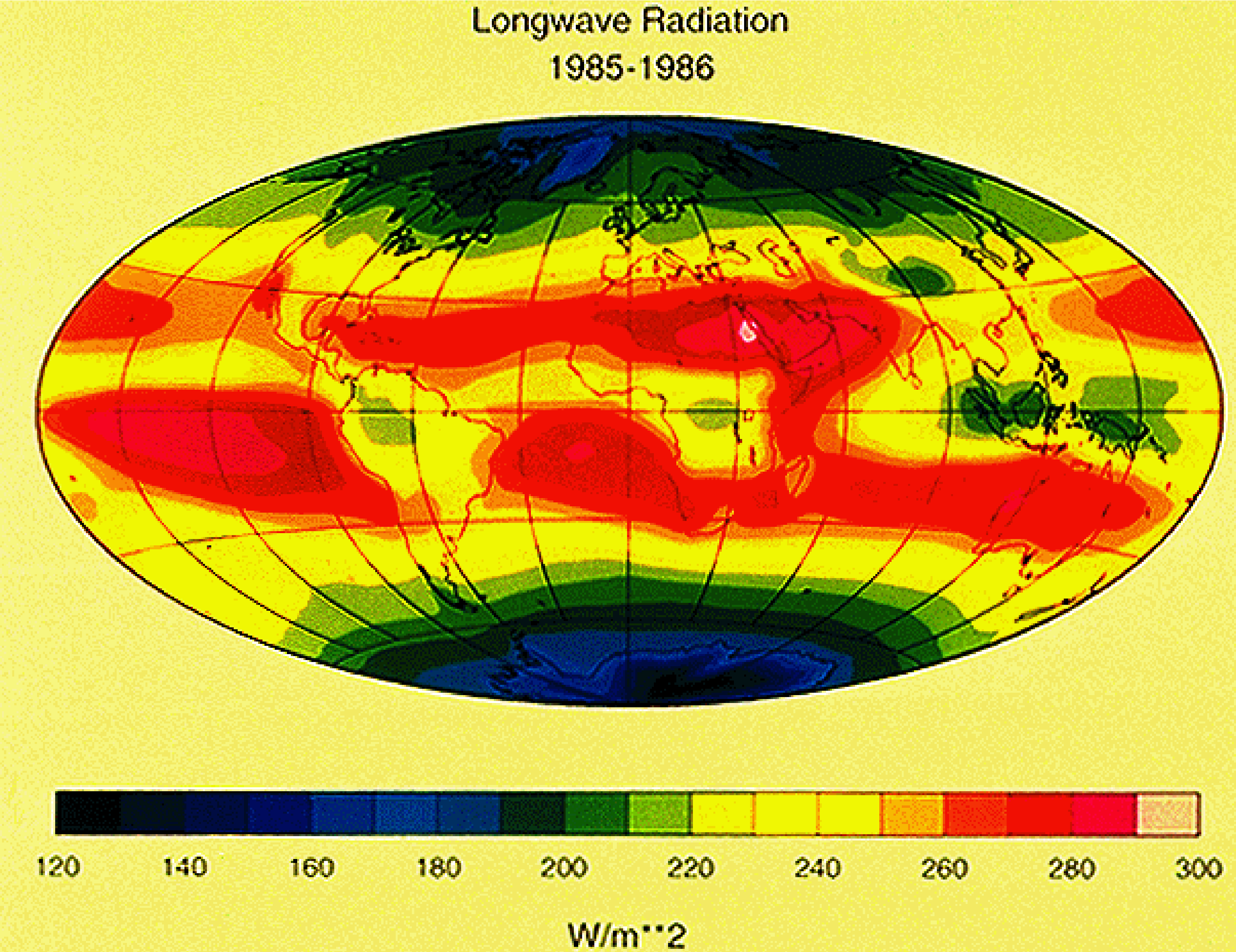
Longwave Radiation
1985-1986
120
140
160
180
200
220
240
260
280
300
W/m**2

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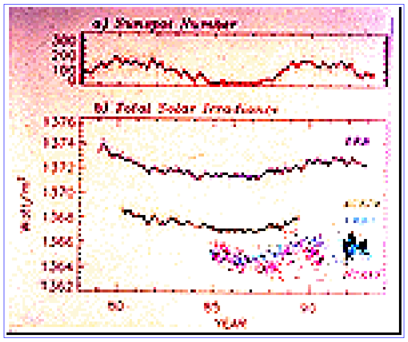
Solar Irradiance Variations



Solar Irradiance Variations

A potentially important effect in climate change is a variation in the solar irradiance (the amount of electromagnetic energy reaching the Earth from the Sun). In Figure 1-04a the sunspot number, a measure of solar activity, is plotted, showing the well-known 11-year sunspot cycle. The total solar irradiance has been monitored for more than a decade (Figure 1-04b), showing a decline of about 0.1 percent between 1979 and 1986, followed by at least a partial recovery. Note the correlation indicated between the sunspot number and total solar irradiance. If the measured variability in total solar irradiance were spectrally uniform, it would imply a change of about 0.3 W/m2 of absorbed solar energy and a corresponding surface temperature change of about 0.2 degrees C. Solar variability of a few tenths of a percent could cause a global temperature change of the magnitude of the observed cooling between 1940 and 1970 (see Figure 3-01a). Moreover, there have been suggestions that the sun might have played a role in the overall warming trend of the past century, shown in Figure 3-01a. Thus we need to monitor solar irradiance on longer time scales. Note in Figure 1-04b that there are offsets between the measurements of the absolute irradiance, even by the best calibrated instruments, e.g., NASA's Nimbus-7/Earth Radiation Budget (ERB) instrument, the Solar Maximum Mission (SMM)/Active Cavity Radiometer Irradiance Monitor (ACRIM), and the Earth Radiation Budget Satellite (ERBS) and NOAA-9 satellite/Earth Radiation Budget Experiment (ERBE)instruments. This implies the necessity of overlapping coverage by successive instruments for successful monitoring. The continous, spaceborne measurements of total solar irradiance indicate an association with activity in the sun's outer layer, the photosphere.

Every effort is being made to provide the maximum amount of continuity in the record of solar irradiance measurements. To avoid gaps that would reduce the scientific value of the ACRIM data set, the possibilities of flying additional instruments on the Space Shuttle, a small spacecraft, NOAA operational satellites, or various EOS missions are being explored.

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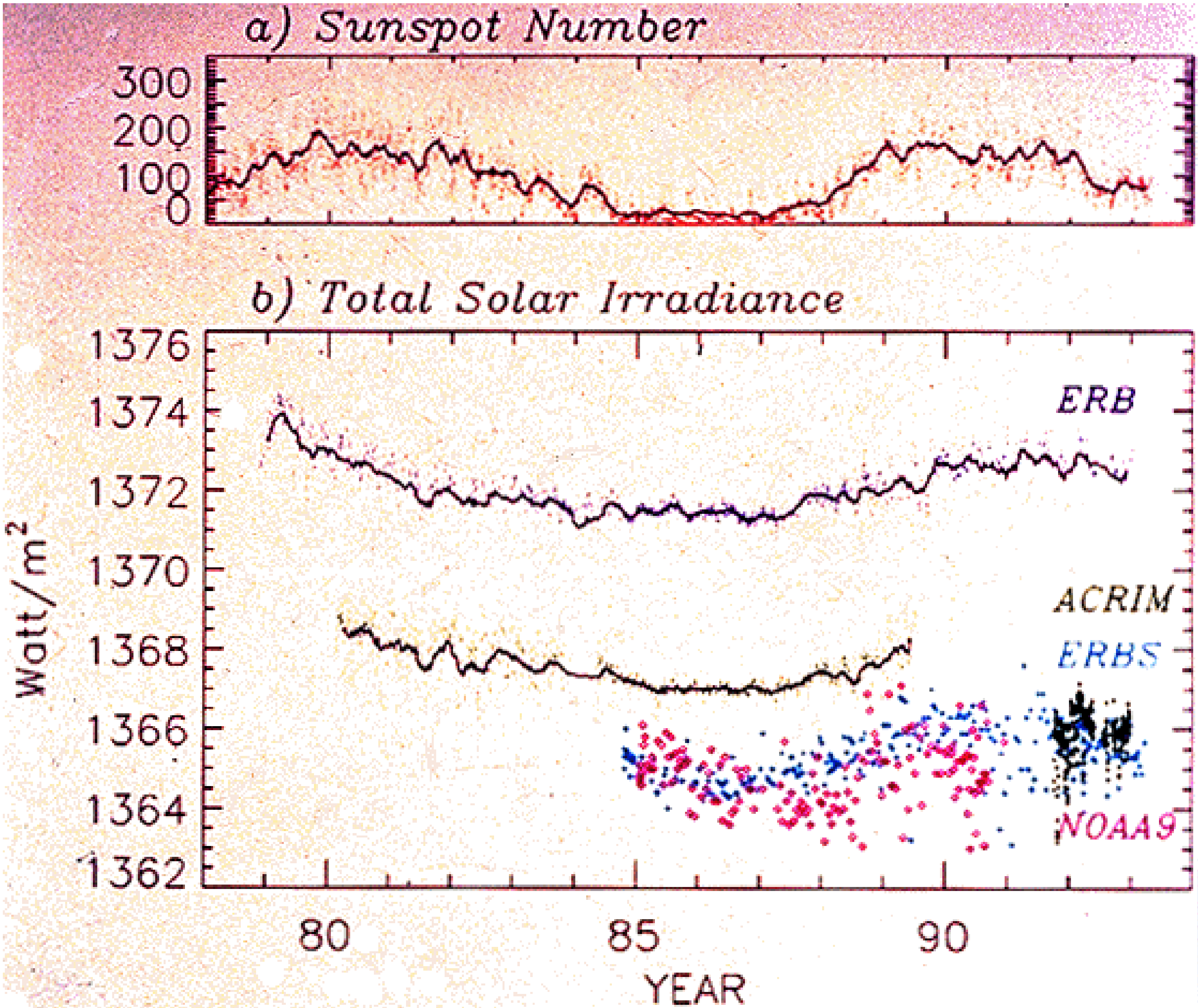
a) Sunspot Number
300
200
100
0
b) Total Solar Irradiance
1376
1374
1372
1370
1368
1366
1364
1362
Watt/m2
ERB
ACRIM
ERBS
NOAA9
80
85
90
YEAR

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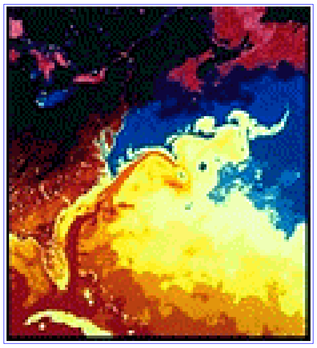
ID: 2-01

Gulf Stream Temperatures



Gulf Stream Temperatures

Ocean currents such as the Gulf Stream are responsible for moving excess heat gained in the tropics to the poles, thus maintaining the Earth's thermal equilibrium. On average, the atmosphere and the ocean are equal partners in the amount of heat they transfer poleward. Sea-surface temperatures are used to determine how much heat is transferred between the atmosphere and the ocean.

The temperature of the ocean also determines how much carbon dioxide can be absorbed from the atmosphere. Knowing how much is absorbed is important because carbon dioxide is one of the major greenhouse gases that may be responsible for global warming.

This thermal infrared image of the northwest Atlantic Ocean was taken from a NOAA satellite using the Advanced Very High Resolution Radiometer (AVHRR) instrument, which is sensitive to changes in the temperature of the ocean's surface. The warmest temperatures (25 degrees C) are represented by red tones, and the coldest temperatures (2 degrees C) by blue and purple tones. The Gulf Stream is clearly visible as a core of warm water moving along the east coast of the United States and turning eastward into the Atlantic near Cape Hatteras, North Carolina.

As the Gulf Stream moves toward the central Atlantic, it releases heat to the atmosphere, so that by the time the Stream reaches the central Atlantic, it has lost its warm core, and its surface waters are no longer distinguishable from the surrounding waters. The area just east of Cape Hatteras sees the largest sustained transfer of heat from the ocean to the atmosphere. Because of this large heat transfer, atmospheric storms tend to intensify in this region.

Critical ocean science questions that scientists hope to answer are: 1) what is the amount of heat transferred by the ocean from the equator to the poles, and how much heat is exchanged between the atmosphere and the ocean? 2) how much carbon dioxide is being removed from the atmosphere by the ocean, and is the rate fast enough to compensate for the amount of carbon dioxide being released into the atmosphere by human activities?

Further research on these questions and other processes manifested in sea surface temperature patterns will be performed using data from a number of EOS instruments, including the Moderate-Resolution Imaging Spectroradiometer (MODIS), the Atmospheric Infrared Sounder (AIRS)/Advanced Microwave Sounding Unit (AMSU)/Microwave Humidity Sounder (MHS), and the Multifrequency Imaging Microwave Radiometer (MIMR), developed by the European Space Agency.

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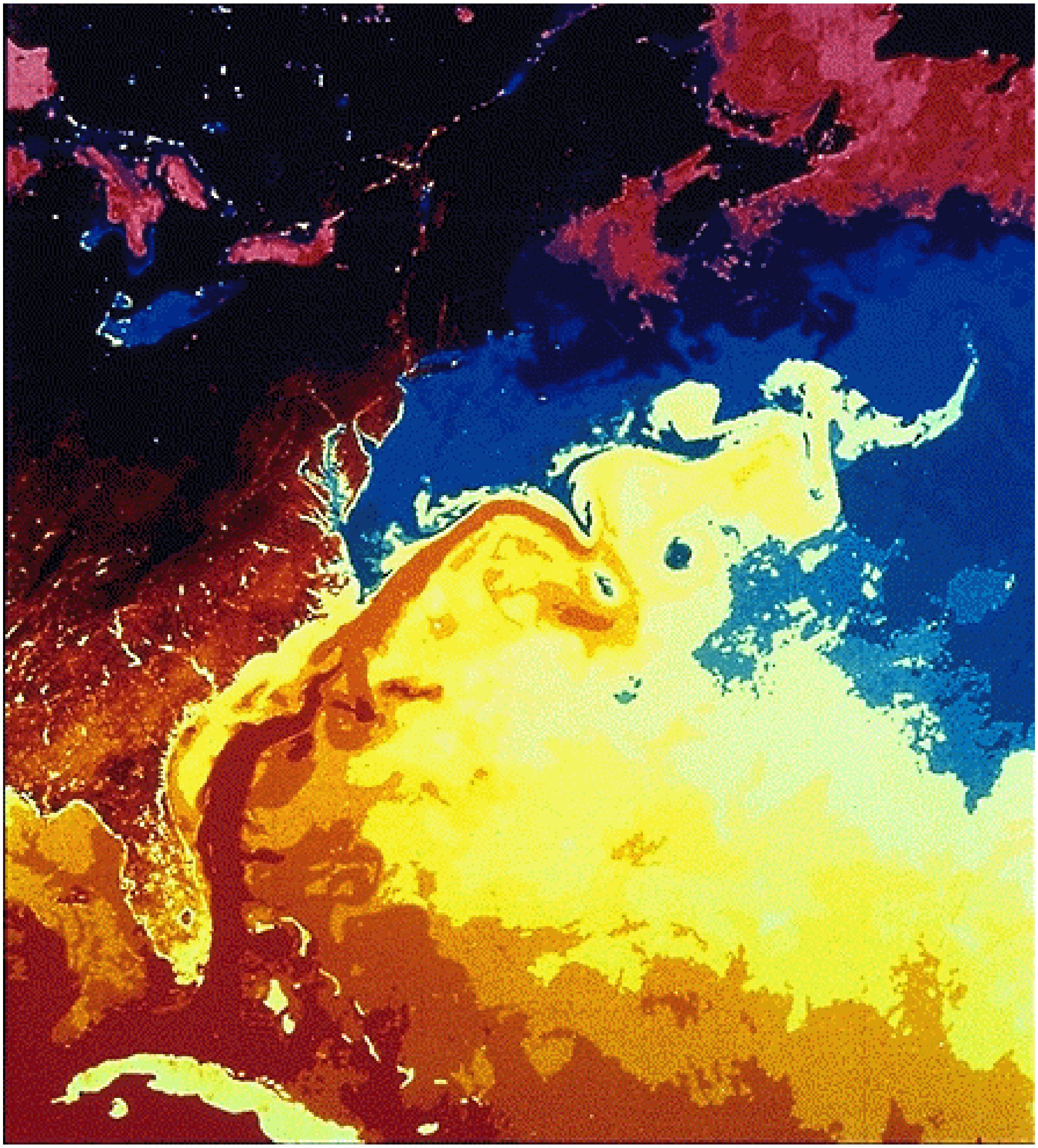

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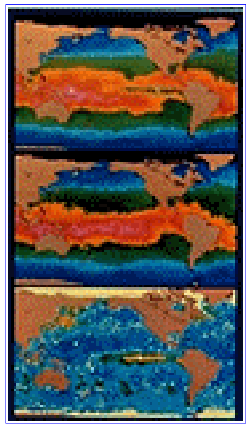
ID: 2-02

El Niño



El Niño

The warm waters of the Western Tropical Pacific supply much of the energy that drives the atmospheric circulation. Generally, a tongue of relatively cool water extends westward along the Equator from South America. This condition forms the basis for "normal" weather in the western Pacific. However, every 4 to 7 years, the tongue of cool water is replaced by warmer water (this is El Niño), and the atmosphere responds dramatically to this large-scale change in sea-surface temperature patterns.

The climatic consequences of an El Niño include changes in the onset and intensity of the Indian monsoon, changes in the frequency, severity, and paths of storms in the Pacific, and the occurrence of short-term regional droughts and floods in many parts of the world. In addition, the El Niño also causes a drop-off in the productivity of the South American fishing industry. The results of these climate changes can be catastrophic. For example, the anomalous climate associated with the 1982-1983 El Niño led to the loss of thousands of lives and damage costing more than $13 billion worldwide.

These three maps of sea-surface temperature were produced to help understand the interrelated set of changes in atmospheric and oceanic circulation in the Pacific during El Niño periods. In the color scale used here, blues indicate cool waters (0 degree C to 12 degrees C); greens represent moderate temperatures (13 degrees C to 24 degrees C); and reds-yellows-magentas represent warm waters (25 degrees C to 30 degrees C).

During most years, the sea-surface temperatures in the Pacific resemble those of January 20, 1984, as is shown in the top image. The warmest waters (marked 1 on the image) are found in the western Pacific near the equator. The tongue of relatively cold water (marked with the numeral 2 on the image) extends westward along the Equator from South America. The source of the cold water is twofold: Southeasterly winds along the Peruvian and Chilean coast cause upwelling of colder water at the coast. The Peruvian current carries this cooler water northward and then westward from the western coast of South America. In addition, the strong, easterly trade winds interact with the ocean surface causing a local transport of water away from the Equator toward both poles, which in turn induces an upwelling of cooler, subsurface water along the Equator.

The middle image shows sea-surface temperatures on January 20, 1983 during the 1982-1983 El Niño. Comparison with the top image shows that the cooler waters associated with the Peru Current and the equatorial upwelling were absent during the El Niño. Satellite monitoring of sea-surface temperatures throughout 1982 and 1983 revealed that a rapid warming of the surface waters in the eastern Pacific near the equator began in August of 1982. The elevated sea-surface temperatures continued until June of 1983. During that period, the easterly trade winds weakened--and actually reversed direction for a few months. The warm surface waters normally pushed by the trade winds to the western side of the Pacific "sloshed" back to the east. The period also was marked by a cessation of upwelling along the equator.

The lower image shows the differences in sea-surface temperature between 1983 and 1984. The differences reveal the extent to which the 1982-1983 El Niño differed from a normal year. In particular, note that along the Equator in the Eastern Pacific (marked by the numeral 3) upwelling had ceased and temperatures were 2 degrees to 6 degrees C warmer than in 1984. Also, large regions of the Western Tropical Pacific (marked by the numeral 4) were 1 degree to 3 degrees C cooler than normal. This general pattern persisted for 10 months.

By studying the El Niño, scientists hope to gain a better understanding of the dynamics of this phenomenon that will enable them to predict its occurrence. Many of the adverse impacts of El Niño-related climate fluctuations could be avoided or reduced by successful forecasts of the phenomenon. For example, a more-complete knowledge of the dynamic interactions that are part of an El Niño would allow policy makers to make decisions to recommend substituting one crop for another (depending on potential flood or drought conditions), to conserve water or prepare for excessive rain, or to prepare for an increased likelihood of forest fires.

Additional capabilities to study the El Niño phenomenon and the many global ramifications associated with it will be provided by future missions such as the Moderate-Resolution Imaging Spectroradiometer (MODIS) scheduled for flight on the EOS satellites.

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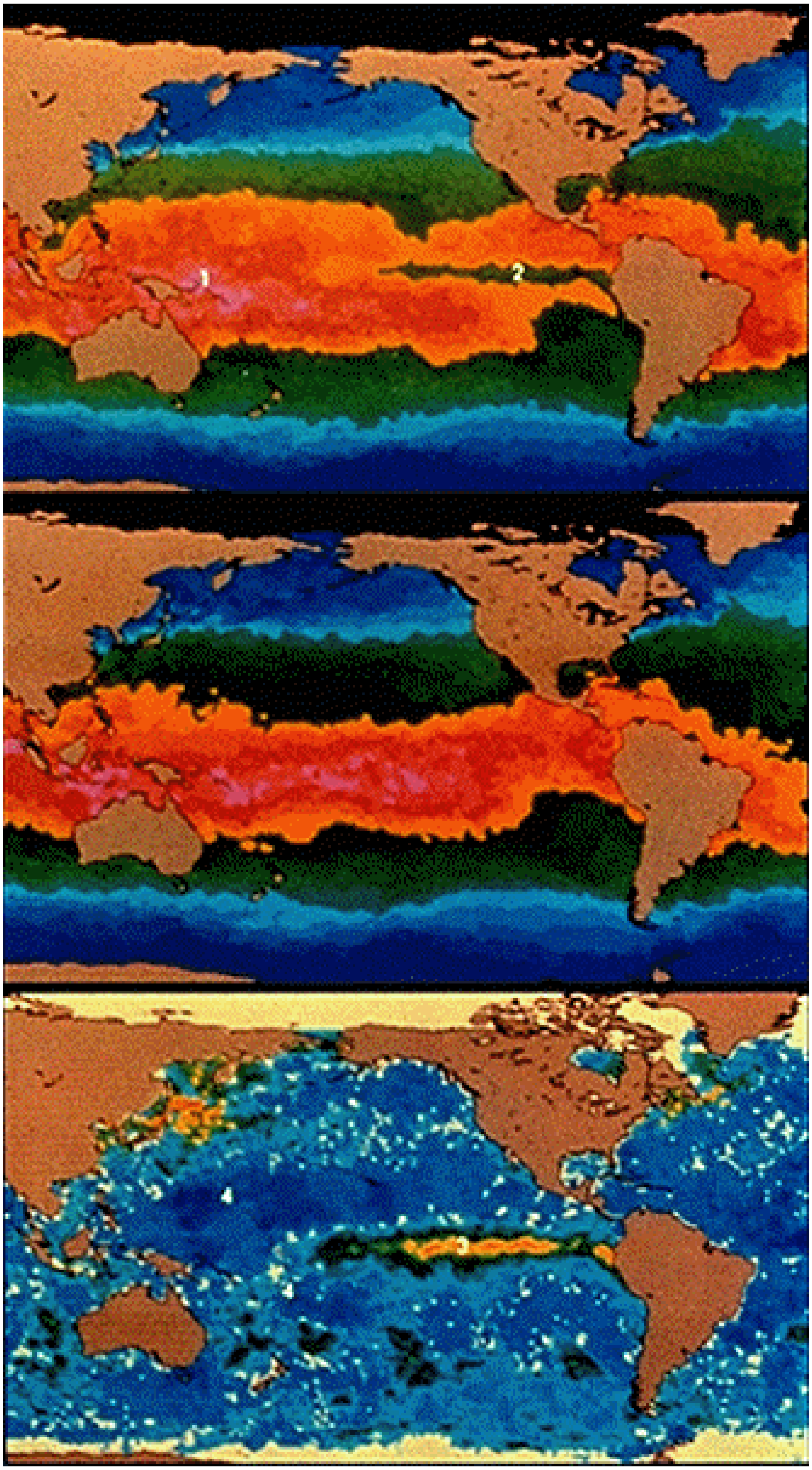
1
2
3
4

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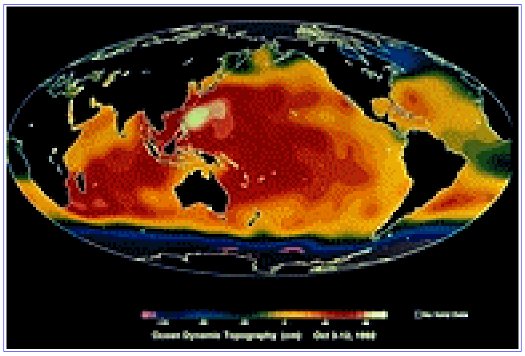
ID: 2-03

Ocean Topography



Ocean Topography

Ocean topography is a measure of sea level relative to the Earth's geoid (a surface on which the gravity field is uniform). Oceanographers use ocean topography maps to calculate the speed and direction of ocean currents in much the same way that meteorologists use maps of atmospheric pressure to calculate the speed and direction of winds.

The highs and lows in the Earth's oceans can be thought of as the oceanic counterpart of atmospheric circulation systems. The existence and basic structure of these systems are constant, but the details of the systems are changing constantly. Therefore, ocean topographic features can be considered the "climate" of the ocean.

This image was produced from preliminary data from the joint U.S.-France TOPEX/Poseidon radar altimeter, a satellite instrument that uses radar to make precise measurements of ocean surface heights.

In this image, the maximum sea level (shown in white) is located in the western Pacific Ocean and the minimum sea level (shown in blue and purple) is around Antarctica. In the northern hemisphere, ocean currents flow clockwise around areas of high sea level, and counterclockwise around areas of low sea level. (This phenomenon is reversed in the southern hemisphere.)

Although this image is derived from only 10 days of TOPEX/Poseidon data, it reveals most of the ocean circulation systems that have been identified by shipboard observations collected over the past 100 years, clearly demonstrating the utility of acquiring Earth system data from orbiting instruments.

Future missions to study the topography of the global oceans include a Solid-State Altimeter (SSALT) provided by the Centre National d'Etudes Spatiales (CNES) and scheduled for flight on the EOS-Altimetry satellite series.

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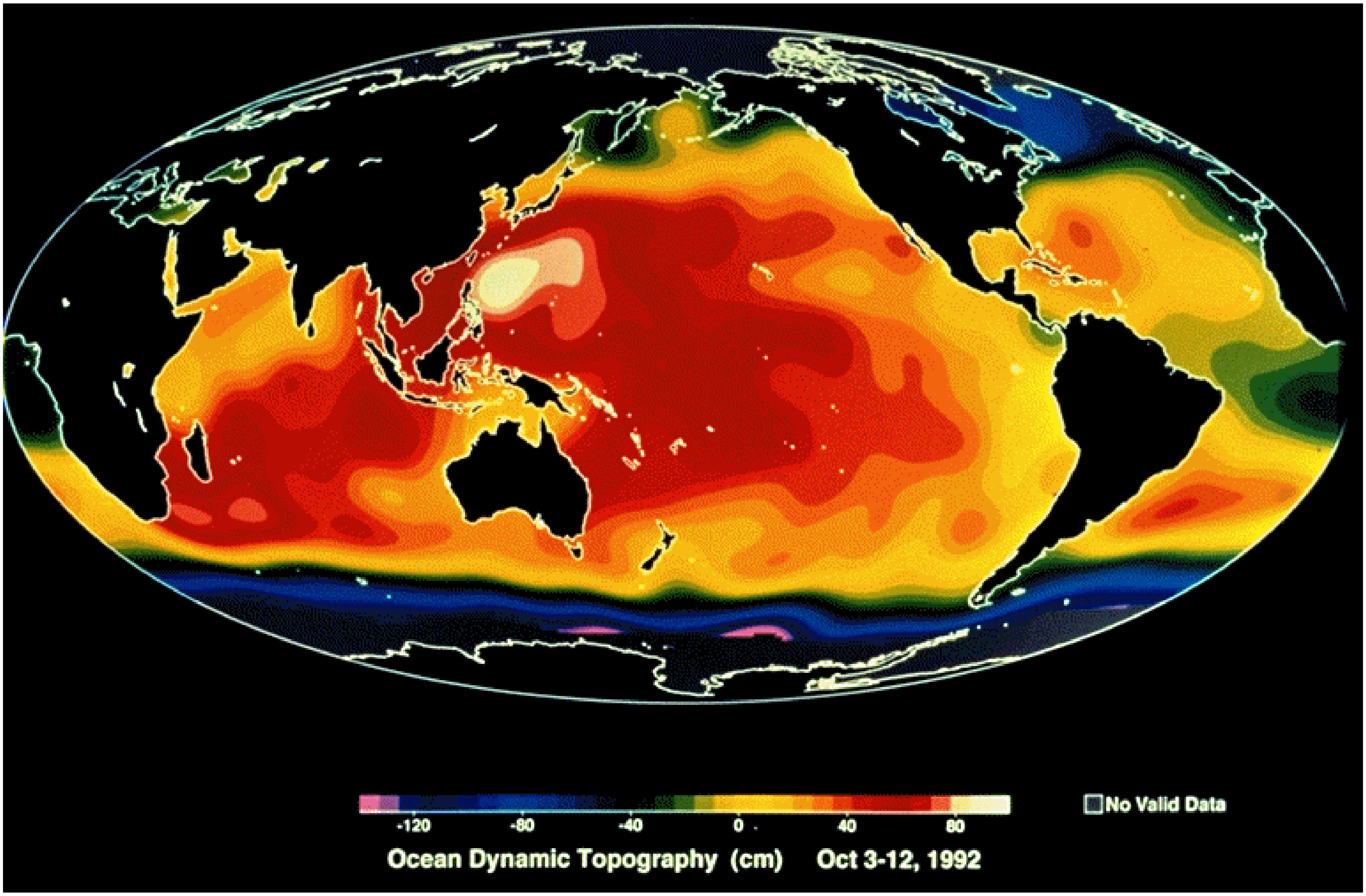
No Valid Data
-120
-80
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40
80
Ocean Dynamic Topography (cm) Oct 3-12, 1992

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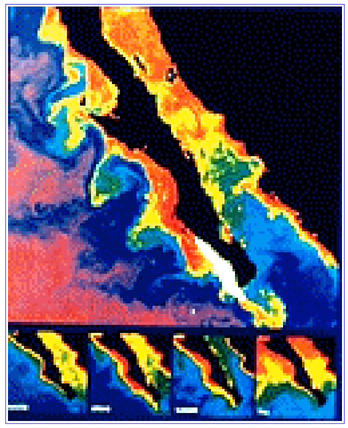
ID: 2-04

Seasonal Baja Ocean Color



Seasonal Baja Ocean Color

The colors in the upper part of the image above are indicators of the abundance of phytoplankton (passively floating or weakly swimming microscopic plant life in the ocean) which serve as food for fish. Purples and blues depict low concentrations; greens and yellows depict moderate concentrations; and oranges and reds depict high concentrations. There is a direct relation between phytoplankton abundance and the measured chlorophyll pigment concentration, calculated from ocean color data collected by the Coastal Zone Color Scanner (CZCS) on NASA's Nimbus-7 satellite. The data were gathered on a single satellite pass on May 12, 1979.

Adjacent to the Pacific coast of Baja, California, there is a stretch of high concentrations of phytoplankton (1) caused by upwelling induced by wind currents. In places, long filaments of this phytoplankton-rich water extend hundreds of kilometers offshore, mixing with the meandering California current (2). Farther south, the Costa Rica current (3) flows north, bringing warm water from equatorial regions to meet the cooler, southward-flowing California current. Near the southern tip of Baja, a cloud/fog bank (the white area) has formed over the cold water at an upwelling site. The high-phytoplankton water of the cold, nutrient-rich coastal waters contrasts sharply with the low-phytoplankton waters of the California and Costa Rica currents further offshore. (These two currents are not easily distinguished in this image because they are both relatively low in phytoplankton.)

Conditions in the Gulf area of Baja are different from those in the Pacific. The southern part of the Gulf is a deep basin. Low-nutrient surface water flowing into this area from the south results in generally low levels of phytoplankton (4), except for a narrow area of upwelling along the coast of Mexico. North of the Midriff Islands (5) there is a shallow basin. Strong tidal currents cause intense mixing as they pass over the shallow subsurface ridges near these islands, bringing deeper, nutrient-rich waters to the surface. The result is high phytoplankton abundance, indicated by reds in the image.

The four smaller images illustrate the marked seasonal variations in the distribution and abundance of phytoplankton in the Baja region. The most striking seasonal change in the Gulf is from low phytoplankton concentrations in the summer to high phytoplankton concentrations in the fall. This increase is due to upwelling induced by favorable northwest winds in the fall, which also result in phytoplankton abundance on the Pacific side of Baja.

Satellite observations have provided the first globally observed patterns of ocean color, previously limited to scattered ship observations in well-traveled sea lanes.

Future plans by NASA to continue ocean color research include the launch of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on the SeaStar mission in the spring of 1995 and the launch of the Moderate-Resolution Imaging Spectro- radiometer (MODIS) and EOS Color instruments on the EOS satellites.

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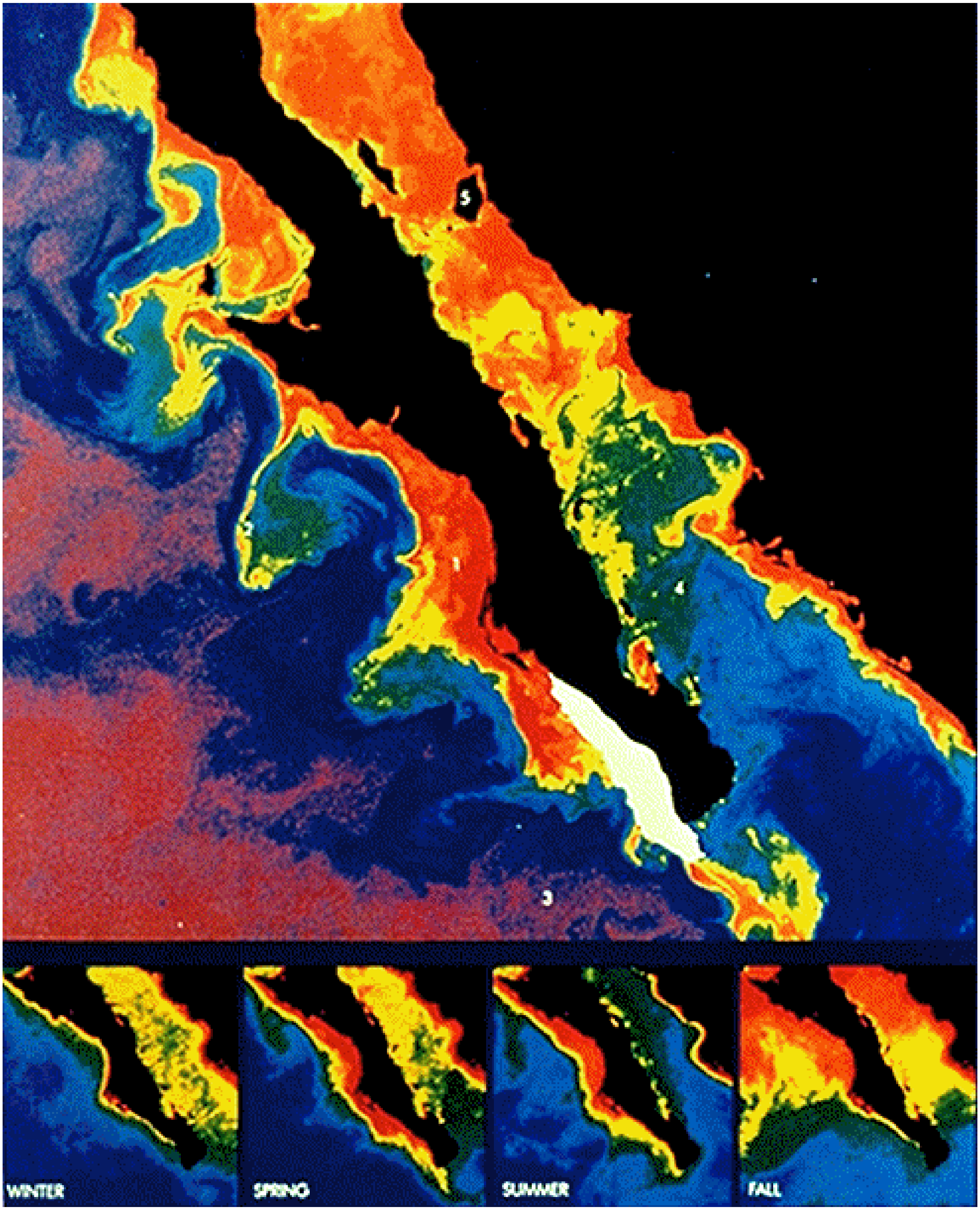
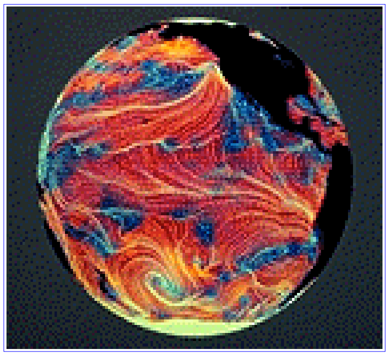

5
2
1
4
3
WINTER
SPRING
SUMMER
FALL

The Earth Observing System Educators' Visual Materials

ID: 2-05

Surface Wind Fields Over The Oceans



Surface Wind Fields Over The Oceans

Wind is the principal engine driving ocean waves and currents and influencing the exchange of heat between the atmosphere and the oceans. Wind also helps to redistribute the sun's heat from the tropics into the cooler polar regions. Wind dynamics, therefore, is crucial to Earth's weather and climate.

Satellites can observe global wind patterns on vast stretches of the ocean surface that are not in the shipping lanes and thus not easily measured by ships and buoys. This image is based on more than 150,000 satellite measurements made during a single day in 1978 by a "scatterometer" instrument on the Seasat satellite. The Seasat scatterometer used a radar beam to measure the roughness of the sea surface, which is caused by wind action. Roughness patterns were then used to derive the wind speeds and directions shown here.

This image represents the surface wind over the Pacific Ocean, with North and South America at the right. The arrows show wind direction and the colors represent wind speed. Blue indicates wind speeds of 1-4 meters/second; gray, 4-6 meter/second; red, 6-16 meters/second; and yellow, 16-20 meters/second.

In areas of low pressure, winds swirl in a counterclockwise direction in the Northern Hemisphere and in a clockwise direction in the Southern Hemisphere. Note the wind speed and direction near storms in the South pacific and near Alaska.

Further research on wind fields over the oceans will be performed using data from a NASA scatterometer (NSCAT) scheduled to fly on the Japanese Advanced Earth Observing Satellite (ADEOS-1) and using data from another NASA scatterometer (SeaWinds) scheduled to fly later on ADEOS-2. The wind-field data will be used for calculating air-sea fluxes of energy, moisture, and chemicals; for modeling upper ocean circulation and tropospheric dynamics; and for improving global weather predictions.

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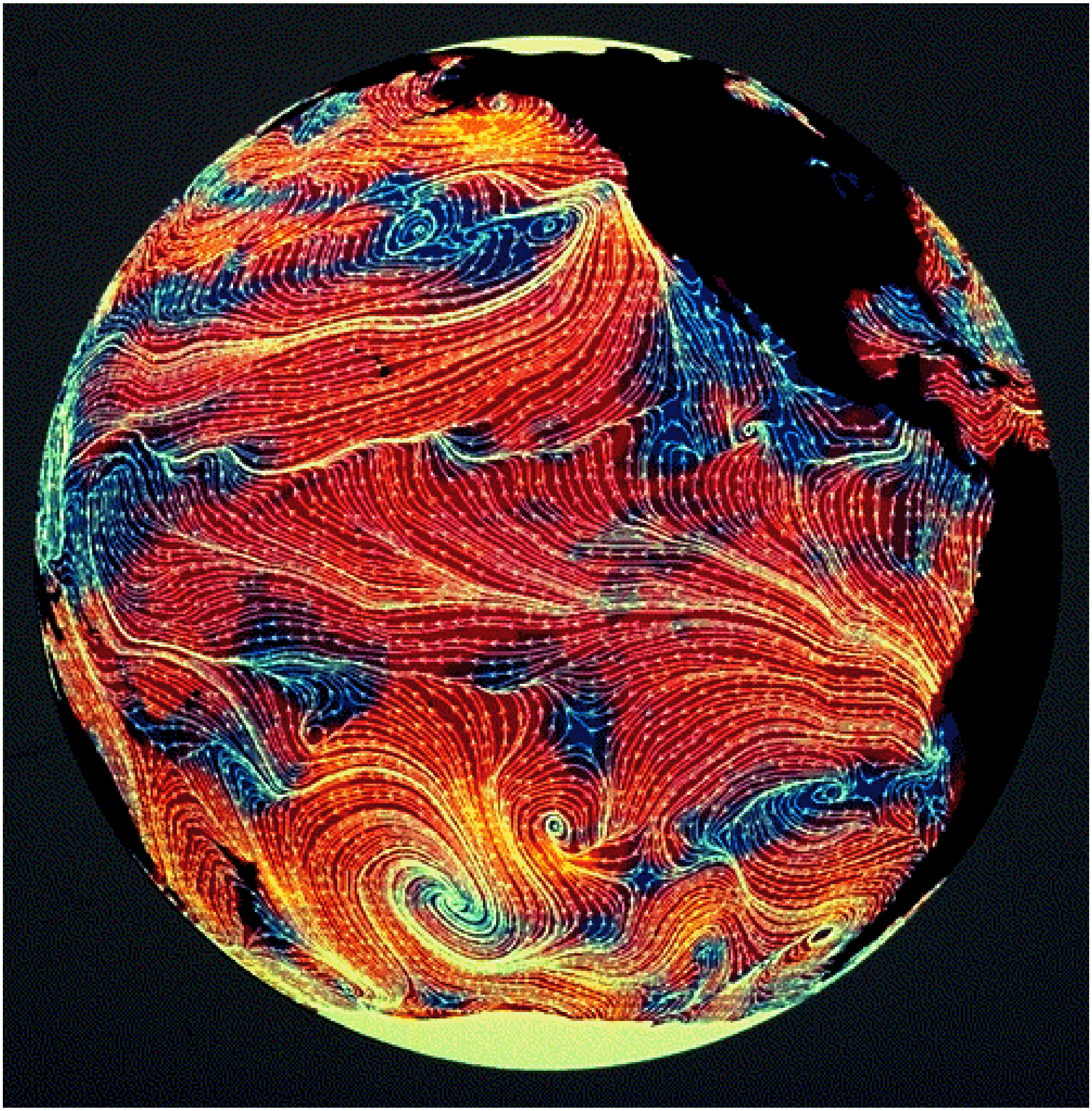
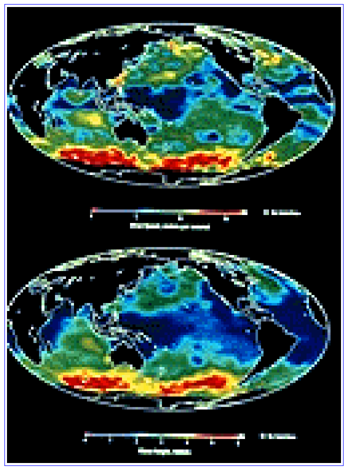


The Earth Observing System Educators' Visual Materials

ID: 2-06

Wind Speed and Wave Height



Wind Speed and Wave Height

The top image shows the global distribution of wind speed at the ocean's surface. The image was constructed from 10 days of data (October 3 to 12, 1993) from a radar altimeter on the TOPEX/Poseidon satellite, a joint U.S.-France Mission. Radar pulses are transmitted from the satellite to the ocean surface below. Wind speed is determined by the strength of the pulses reflected by the ocean's surface and returned to the satellite. A calm sea serves as a good reflector and returns a strong radar pulse. On the other hand, a rough sea tends to scatter the radar signals and returns a weak pulse. In this image, the strongest winds (about 15 meters per second, or 54 kilometers per hour) are found in the Southern Ocean and are indicated by red. The highest waves also are located in this region (see the bottom image of wave height). In general, there is a high degree of correlation between wind speed and wave height. The weakest winds (represented by magenta and dark blue) are found in the western tropical Pacific Ocean, the tropical Atlantic Ocean, and the tropical Indian Ocean.

The bottom image indicates the wave heights in the oceans during the same 10-day period. Wave height is determined by the shape of the radar pulse returned by the ocean's surface. A calm sea with low waves returns a condensed pulse, whereas a rough sea with high waves returns a stretched pulse. This phenomenon occurs because, in a calm sea, nearly every portion of the sea's surface is the same distance below the satellite, while the wave crests in a rough sea may be several meters nearer to the satellite than the wave troughs. In this image, the highest waves occur in the Southern Ocean, where waves up to 6 meters high (represented in red) are found. The lowest waves (indicated by dark blue) are found primarily in the tropical and subtropical oceans, where the winds tend to be lighter.

Simultaneous observations of wind speed and wave height will help to improve forecasts of ocean waves. Such forecasts are a great value to ocean-bound shipping interests; they help to protect lives and property as well as to plan the most economical routing of ships. Also one of the key scientific issues of Mission to Planet Earth addressed by these observations is the exchange of energy between the atmosphere and the ocean. Strong winds favor increased energy exchange.

Future missions include a Solid-State Altimeter (SSALT) provided by the Centre National d'Etudes Spatiales and scheduled for flight on the EOS-Altimetry satellite.

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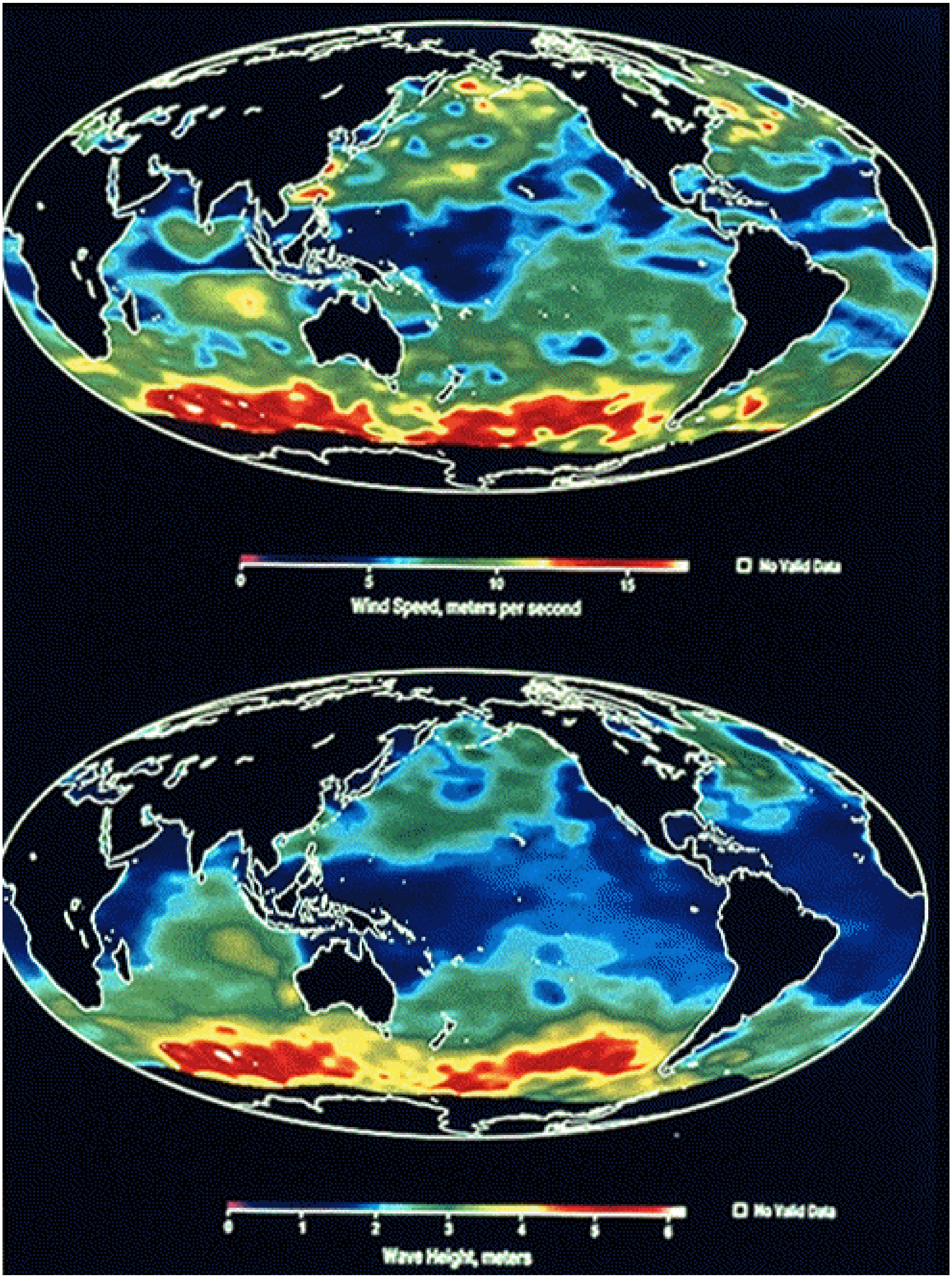
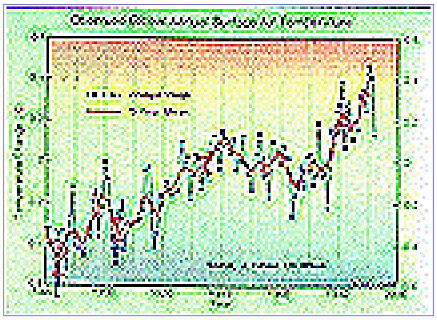
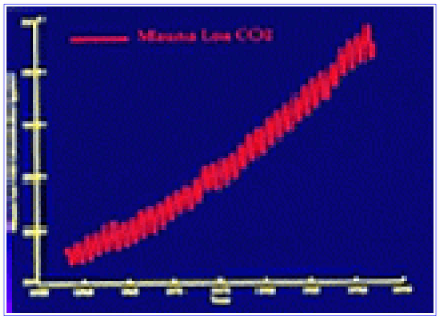

0
5
10
15
No Valid Data
Wind Speed, meters per second
0
1
2
3
4
5
6
No Valid Data
Wave Height, meters

The Earth Observing System Educators' Visual Materials

ID: 3-01 a,b

Surface Air Temperature Change





Surface Air Temperature Change

Figure 3-01a (top) presents data showing that the global air temperature at the Earth's surface has increased about 0.5 degrees C during the pastcentury. These data were gathered from about 2000 locations around the world. Points on the blue line indicate the differences between the annual temperature averages and the 1951-1980 30-year average. The large jumps between points on this line show that average temperatures very widely from year to year. Overall, however, average air temperatures at the Earth's surface have increased.

The red line was plotted as a 5-year "running average" to smooth out annual jumps and highlight the overall trend. The running average is obtained by averaging the temperatures for a 5-year period. The averages are plotted at the mid-point of those years. For example, the last running-average point plotted is for 1990; it is an average of the five annual points for 1988-92. Thus, the red, 5-year running average indicates more clearly the warming trend in global air temperatures.

The warming trend indicated in the graph is important because it provides physical evidence in support of the predictions of climate models. These models predicted that an increase in atmospheric carbon dioxide (CO_2) would cause a heightened greenhouse effect, which in turn would cause a rise in global temperatures. Figure 3-01b (bottom) shows that average atmospheric carbon dioxide concentrations observed at Mauna Loa, Hawaii have increased approximately 40 parts per million by volume (ppmv) since 1958. This increase is believed to be largely because of human activity. (The current concentration of about 353 ppmv indicates that an alarming increase of 25 percent has occurred over the pre-industrial concentration of 280 ppmv that existed some 200 year ago.)

Superimposed on the long-term increase in Figure 3-01b are the seasonal variations, due primarily to the withdrawal and production of CO_2 by the terrestrial boita, with minima during the Northern Hemisphere summers (when global photosynthetic activity is greatest) and maxima 6 months later.

Futher scientific investigations and satellite-based observations planned as part of the MTPE/EOS Program will elucidate the cause of global warming and help to provide the predictive capability needed to assess future changes in surface air temperature and the global climate.

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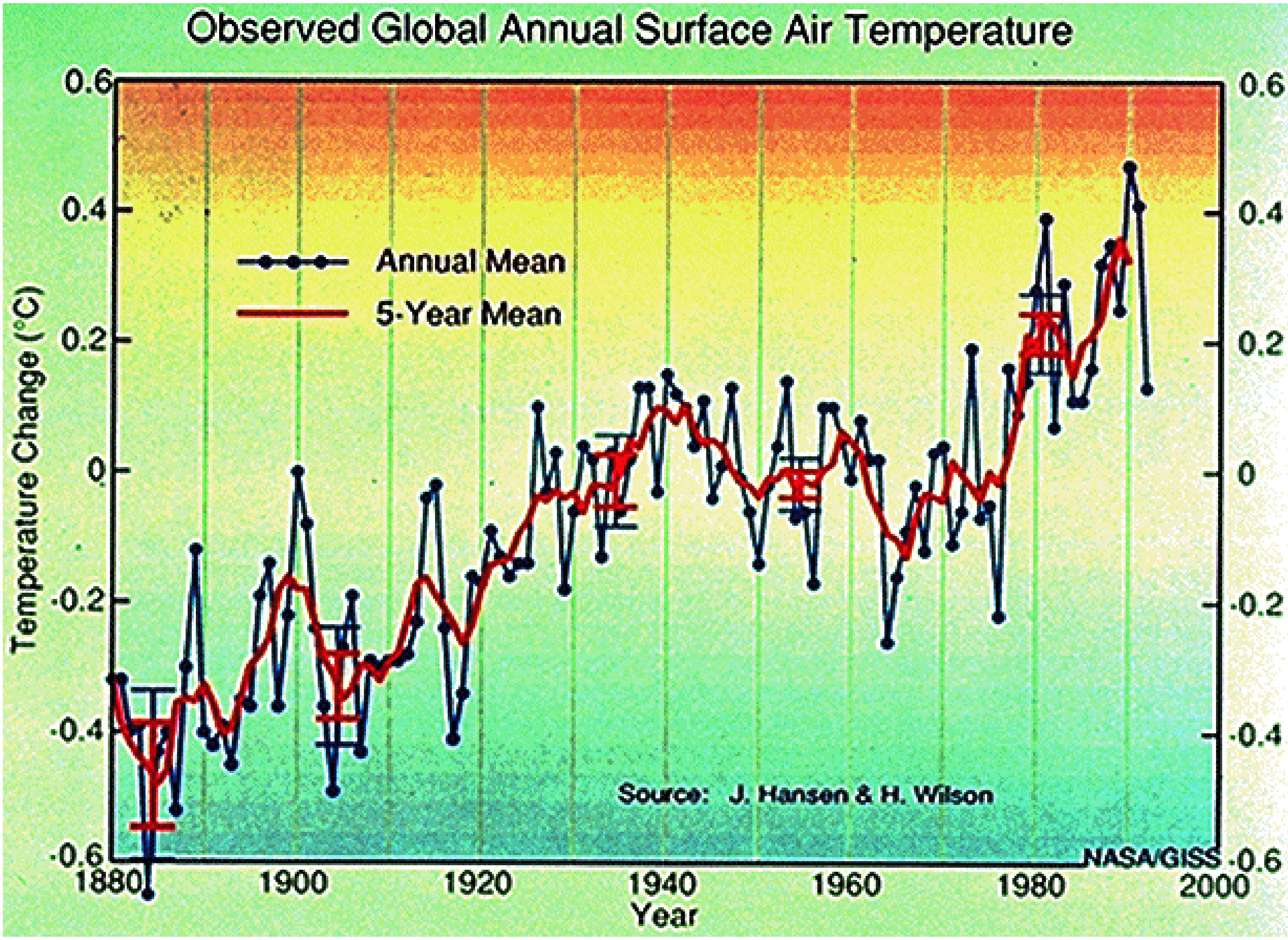
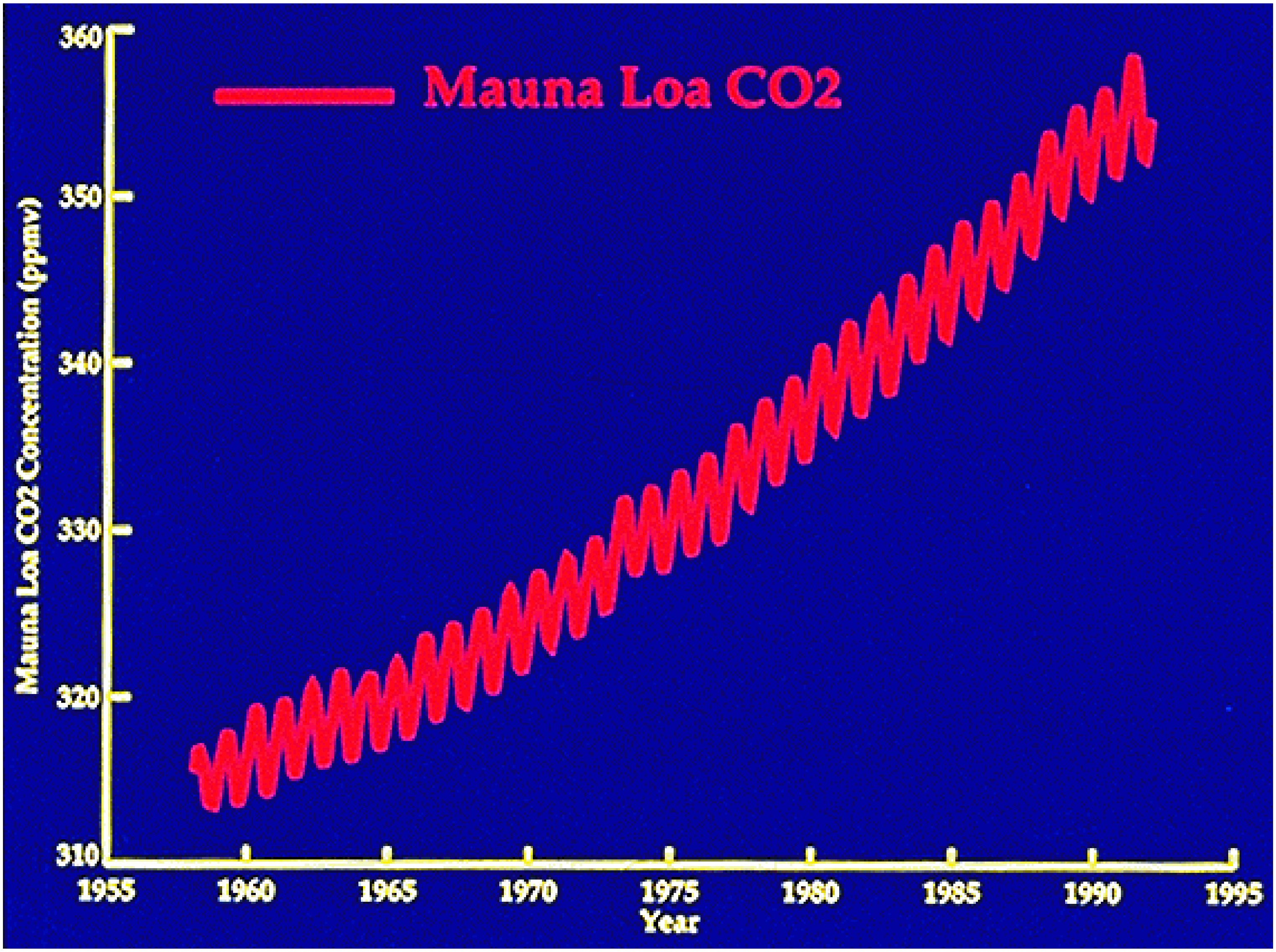
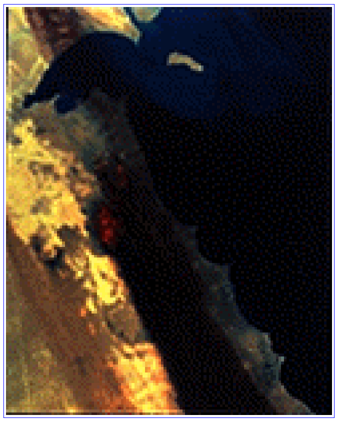

Observed Global Annual Surface Air Temperature
Annual Mean
5-Year Mean
Source: J. Hansen & H. Wilson
NASA/GISS
Temperature Change (°C)
Year
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1880
1900
1920
1940
1960
1980
2000


Mauna Loa CO2
Mauna Loa CO2 Concentration (ppmv)
360
350
340
330
320
310
1955
1960
1965
1970
1975
1980
1985
1990
1995
Year

The Earth Observing System Educators' Visual Materials

ID: 3-02

Smoke From The Kuwait Oil Well Fires



Smoke From The Kuwait Oil Well Fires

At the end of the Persian Gulf War in the spring of 1991, 732 oil wells were set ablaze in Kuwait. Some 550 wells were still burning in May and June, when a group of scientists began to study the properties and climatic impact of the dense smoke that rose from them.

In this image, taken from the Landsat-5 Thematic Mapper during the study, the fires appear as red dots. The black smoke plume extends south from Kuwait along the Persian Gulf coast into Saudi Arabia.

Along much of the coast, the smoke plume remained confined to a strip about 25 kilometers wide in areas near the fires. As the plume moved off the Arabian Peninsula toward the Gulf of Oman and India, it widened to about 60 kilometers and became thinner. The smoke plume not only was relatively narrow, but limited in height, typically having a base at about 0.5 kilometers and a top between 3 and 4 kilometers.

Using an instrument called the Cloud Absorption Radiometer aboard a C-131A aircraft from the University of Washington, scientists were able to measure scattered radiation deep within the smoke layer. These data provided information about the composition of the smoke layer.

One of the objectives of the study was to predict how extensively the smoke from the fires would spread, and what effect the smoke would have on global climate. Although the scientists concluded that the smoke from the Kuwait oil fires would be confined to the Gulf region, the data they obtained on smoke characteristics will add to our understanding of the effect of more-extensive fires on global climate.

Beginning in 1998, such instruments as the Moderate-Resolution Imaging Spectroradiometer (MODIS) and the Multi-angle Imaging Spectro-Radiometer (MISR) planned as part of the EOS Program, will provide observations of fires and the smoke produced by them routinely on a global scale.

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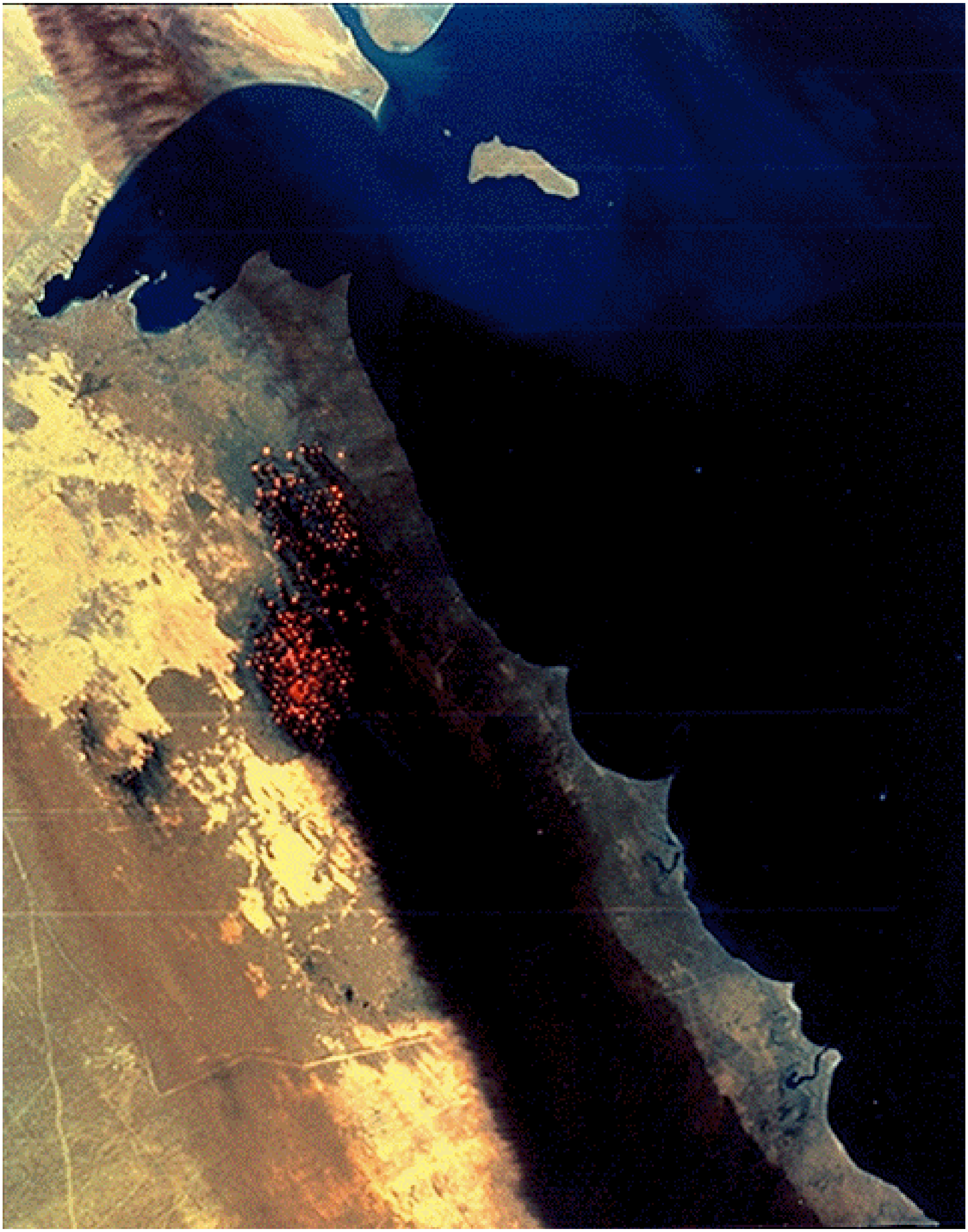
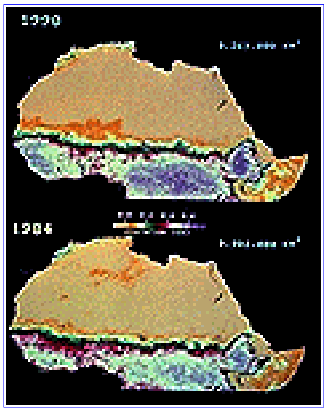


The Earth Observing System Educators' Visual Materials

ID: 4-01

Expansion and Contraction of the Sahara Desert



Expansion and Contraction of the Sahara Desert

These images, constructed using multispectral data from Advanced Very High Resolution Radiometers (AVHRR) on NOAA satellites, show the changes in the extent and area of the Sahara Desert from 1984 to 1990. The desert is shown in shades of brown, and full vegetative color is shown in purple. Colors in between brown and purple indicate intermediate amounts of vegetation.

This comparison shows that the Sahara Desert grew smaller between 1984 and 1990, but the contraction of the desert does not necessarily mean that the Sahara is getting smaller over the long term. Between 1980 and 1984 the desert grew steadily larger. Data gathered during this four-year period showed the southern boundary of the Sahara creeping southward as much as 240 kilometers.

In fact, satellite observations between 1980 and 1990 showed a fluctuation between expansion and contraction of the Sahara Desert. The overall 10-year trend, however, is an expansion of the desert.

Satellite observations of desert boundaries provide important information for scientists. In the long term, scientists look for signs of land degradation, or desertification. The observations also provide very important, short-term information. For example, satellite information about vegetation and desertification allows scientists to warn governments and policy makers of possible impending famine and to take steps to facilitate early relief efforts.

In the near future, data from such instruments as the Moderate-Resolution Imaging Spectroradio-meter (MODIS), scheduled for flight on the EOS satellites and the Enhanced Thematic Mapper (ETM), scheduled for flight on Landsat-7, will provide such information routinely and globally.

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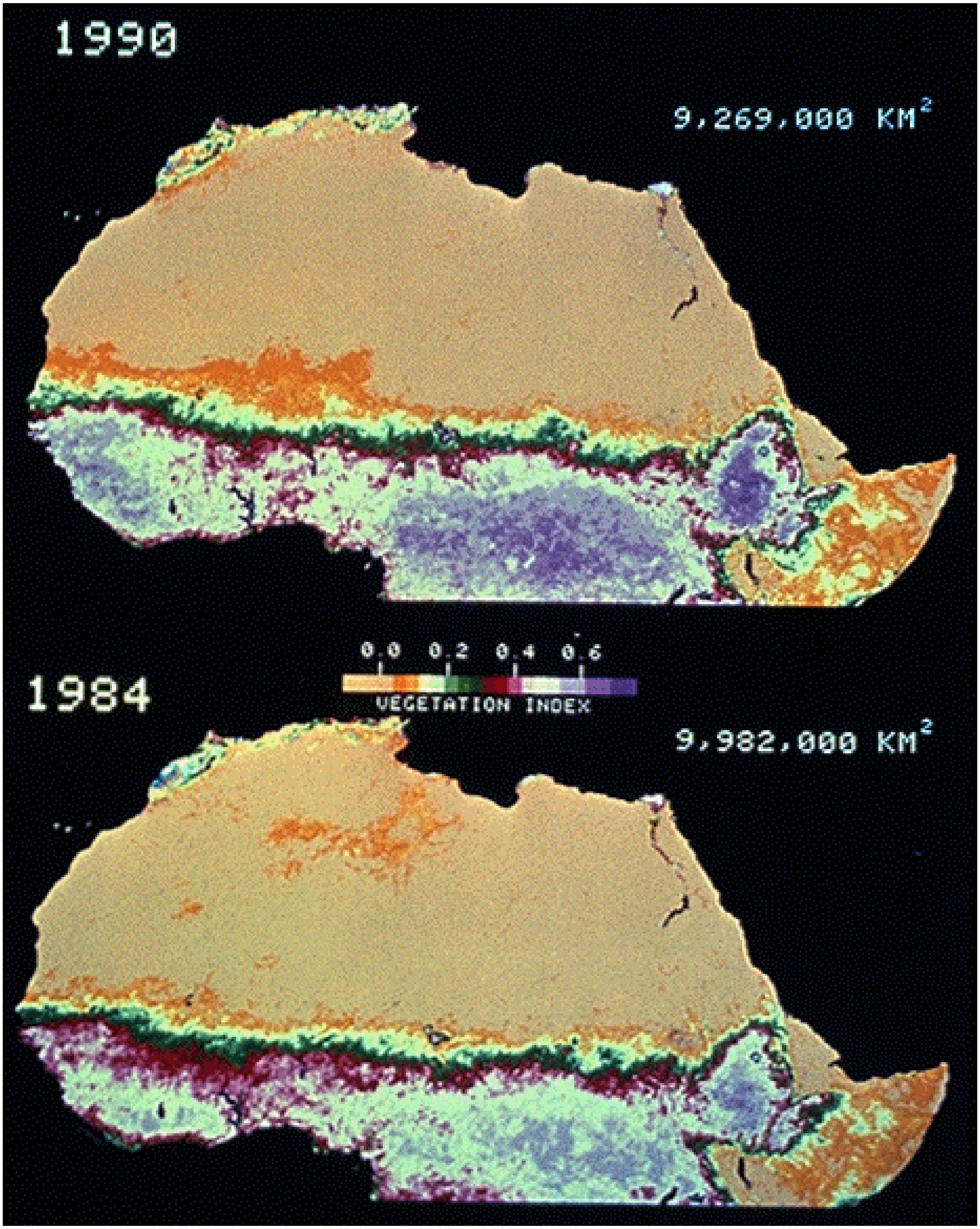
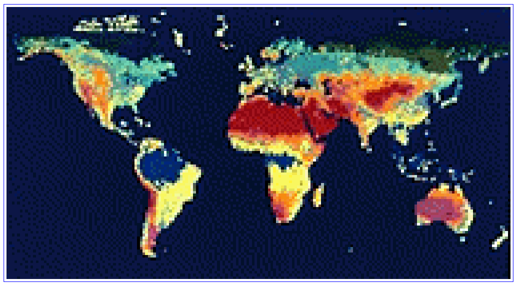

1990
9,269,000 KM²
0.0 0.2 0.4 0.6
VEGETATION INDEX
1984
9,982,000 KM²

The Earth Observing System Educators' Visual Materials

ID: 4-02

Global Vegetation Index



Global Vegetation Index

Global terrestrial ecosystems play a key role in sustaining life on Earth. Only recently have we begun to understand how the thin film of living matter on Earth is sustained by global-scale biogeochemical cycles. Closely related to the biogeochemical cycles are changes in the populations of life forms within the ecosystems of the world, both in numbers of species and in the abundance of individuals within the species. Although such changes are not new, it is apparent that they are now occurring at an accelerated rate, and that human beings, comparatively recent agents of global modification, are the cause of most of this accelerated change. If we are to preserve the unique environment of the Earth, we must understand the role of natural biological diversity in maintaining the global balance of this environment and the extent to which the world's ecosystems must be preserved in order to maintain the conditions desirable for human habitation.

A key scientific question is the role of terrestrial ecosystems in absorbing the excess atmospheric carbon dioxide generated by mankind since the beginning of the industrial revolution. To investigate this question, a global perspective is needed and can only be provided by space-based observations, which are repeatable and non-destructive.

One aspect of this question is illustrated in the image where a map of the global "normalized difference vegetation index" depicts the state of vegetation during August 1987. The data used in the image were acquired by the Advanced Very High Resolution Radiometer (AVHRR) on a NOAA satellite. Dark-blue and green areas represent dense vegetation, and pink and dark-red areas represent sparse vegetation.

In the future the Moderate-Resolution Imaging Spectroradiometer (MODIS) on the EOS satellites and the Enhanced Thematic Mapper (ETM) on Landsat 7 will provide such information routinely as part of the MTPE Program.

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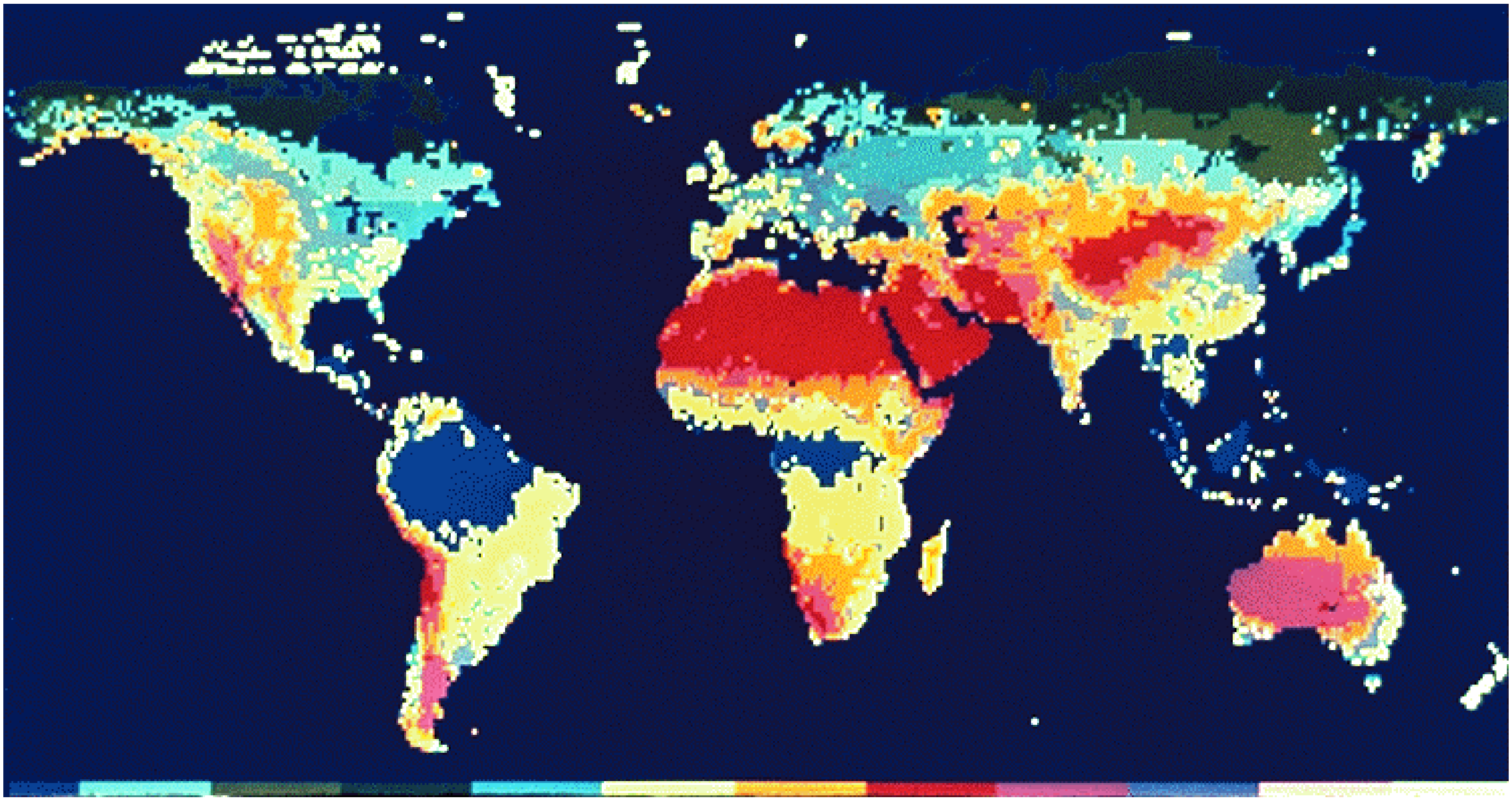
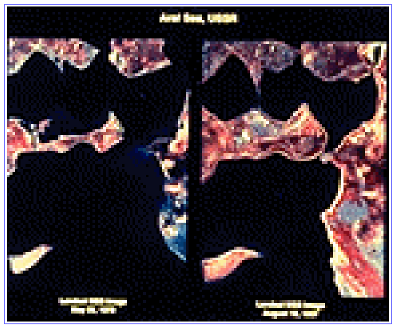


The Earth Observing System Educators' Visual Materials

ID: 4-03

The Aral Sea in the former USSR



The Aral Sea in the former USSR

Large bodies of water have a moderating influence on local climate. Regions that are distant from any large body of water tend to have a continental climate, characterized by more-severe temperature extremes. Water also is extremely important to local ecological conditions, helping to determine which life forms can thrive (or survive) in a particular area.

These Landsat Multispectral Scanner (MSS) images show the effects of the reduced water flow to the northern Aral Sea, once one of the Earth's largest bodies of land-locked water. Since 1960, the sea has lost more than 40 percent of its surface area, and 60 percent of its volume. The associated drop in sea level has lowered the surrounding water table. The cause of the depletion of the Aral Sea is the rerouting of two large rivers for the irrigation of cotton fields. The two rivers were major sources of fresh water to the Aral Sea.

Between 1973 and 1987, a land bridge was exposed, separating the northern, smaller section of the Aral Sea from the larger, southern section. Reduced water flow, coupled with evaporation, has had three primary effects: first, the remaining water has become extremely salinized; second, the moderating effect of the Aral Sea on local climate has diminished, resulting in hotter summers, colder winters, and a decreased growing season; third, over 20,000 square kilometers that were once submerged now are exposed. (The exposed sea bed shows up as a bright strip at the water's edge.) Dust storms raise up massive amounts of salt from the exposed sea bed and move it hundreds of kilometers away. As the salt moves out of the sea bed and into the surrounding land, crop production is reduced.

Moreover, the salt-laden fields require increased irrigation to achieve the same level of production as before. To accommodate this need, more fresh water must be taken from rivers that otherwise would feed the Aral Sea, resulting in a cycle that causes even greater depletion of the Aral Sea.

Increasingly, a major focus of the MTPE Program will be to assess the regional impact of global environmental changes on agricultural and industrial development.

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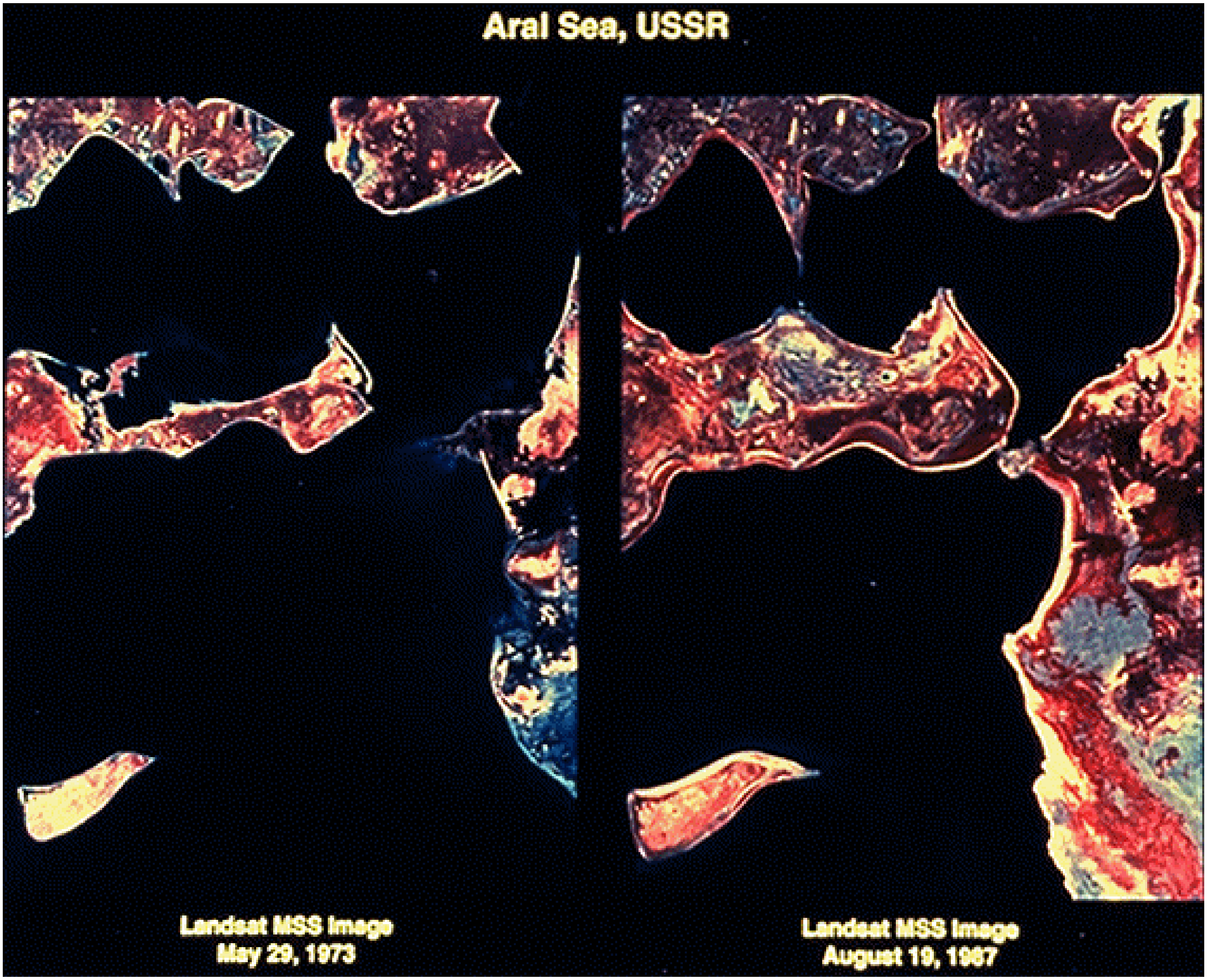
Aral Sea, USSR
Landsat MSS Image
May 29, 1973
Landsat MSS Image
August 19, 1987

The Earth Observing System Educators' Visual Materials

ID: 4-04 a,b

Vanishing Old-Growth Forest in the Pacific Northwest

4-04a. Vanishing Old-Growth Forest in the Pacific Northwest

4-04b. Olympic Peninsula Logging Activity

Deforestation is usually associated with activities in the tropical rainforests of South America, but it can be seen to be a serious problem in temperate zones of the Earth as well.

Clear-cutting of the late-successional or "old growth" evergreen trees in the national forests of the U.S. Pacific Northwest is causing a high degree of habitat fragmentation. Logging of these ancient forests has destroyed the continuity of the forests; large portions of the forests have been cut into small segments by roads leaving thousands of juvenile tree farms of 40 to 60 acres. This fragmentation tends to destroy the habitats required by many species of animals such as the spotted owl and native salmon (see ID: 4-07).

Extensive mapping has shown that a little more than 10 percent of the original 25-million-acre forest that once stretched from Northern California to the Canadian border is now intact. This great swath of trees, including species like the Pacific yew, which contains a cancer-fighting compound, and many plants and animals in danger of being lost forever, is generally considered the biggest and richest of American forests.

Image 4-04a shows a portion of Mount Hood National Forest in western Oregon. Dark-red areas represent old growth; light-red areas represent regrowth; and pink areas are places where young saplings have appeared. Blue areas indicate lack of vegetation due to logging.

Image 4-04b, constructed using Landsat data, highlights the deforestation caused by logging in the Olympic Peninsula in the state of Washington. Yellow areas represent regions logged between 1973 and 1982. Red areas represent regions logged between 1982 and 1988.

In accordance with U.S. Forest Service policy, almost all of the cut areas in the national forests have been replanted with new trees, but this will not be apparent in satellite images until the trees are about 2-3 years old.

Forests are important not only for their role in maintaining biological diversity but also because of their role in global climate. They are a significant factor in taking carbon dioxide, the primary anthropogenic greenhouse gas, out of the atmosphere. Increased deforestation could lead to a greater build-up of greenhouse gases in the atmosphere with consequent global warming.

One of the major objectives of the MTPE Program is to provide a scientific basis for establishing sound environmental policy decisions which may subsequently impact industrial and agricultural development.

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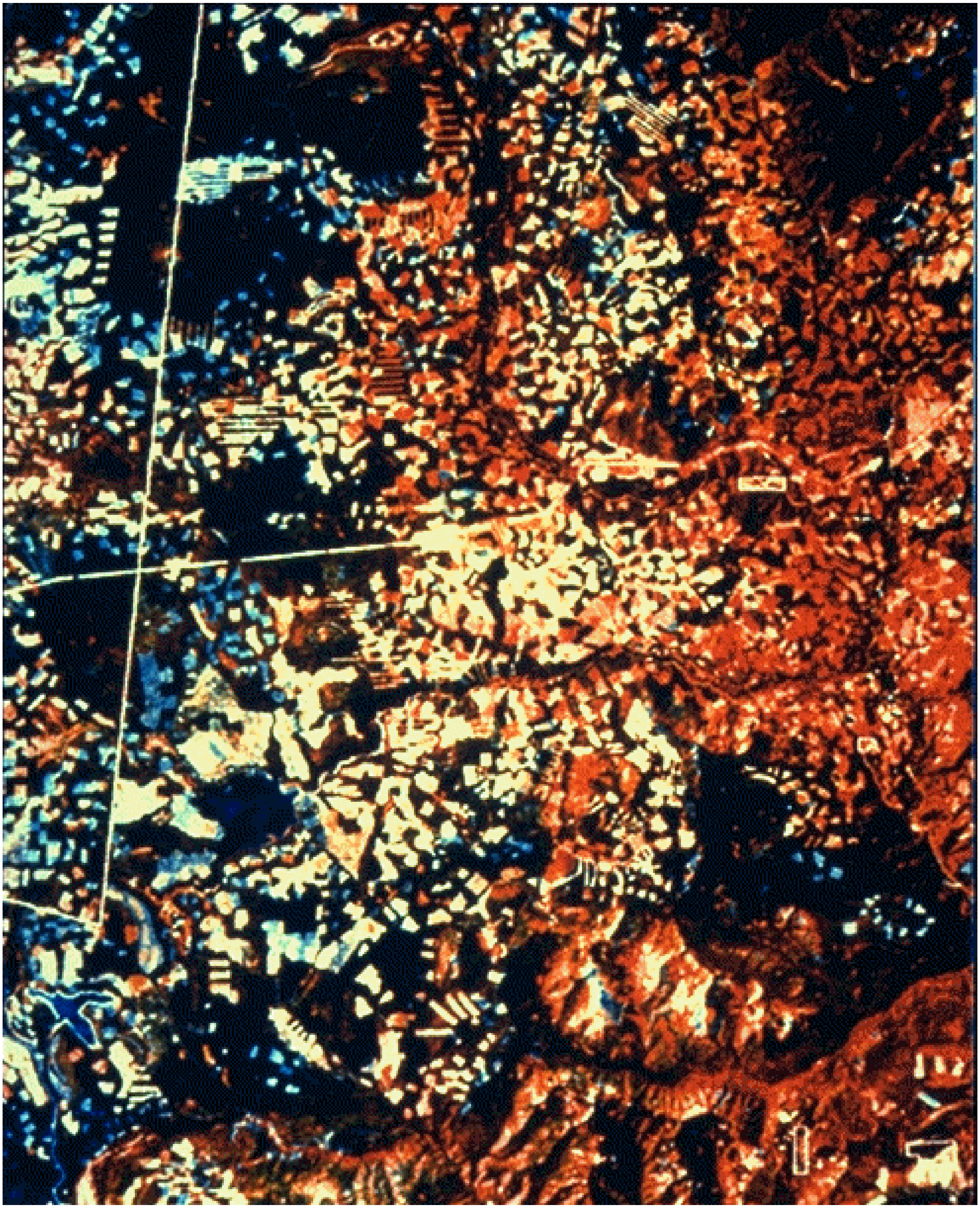
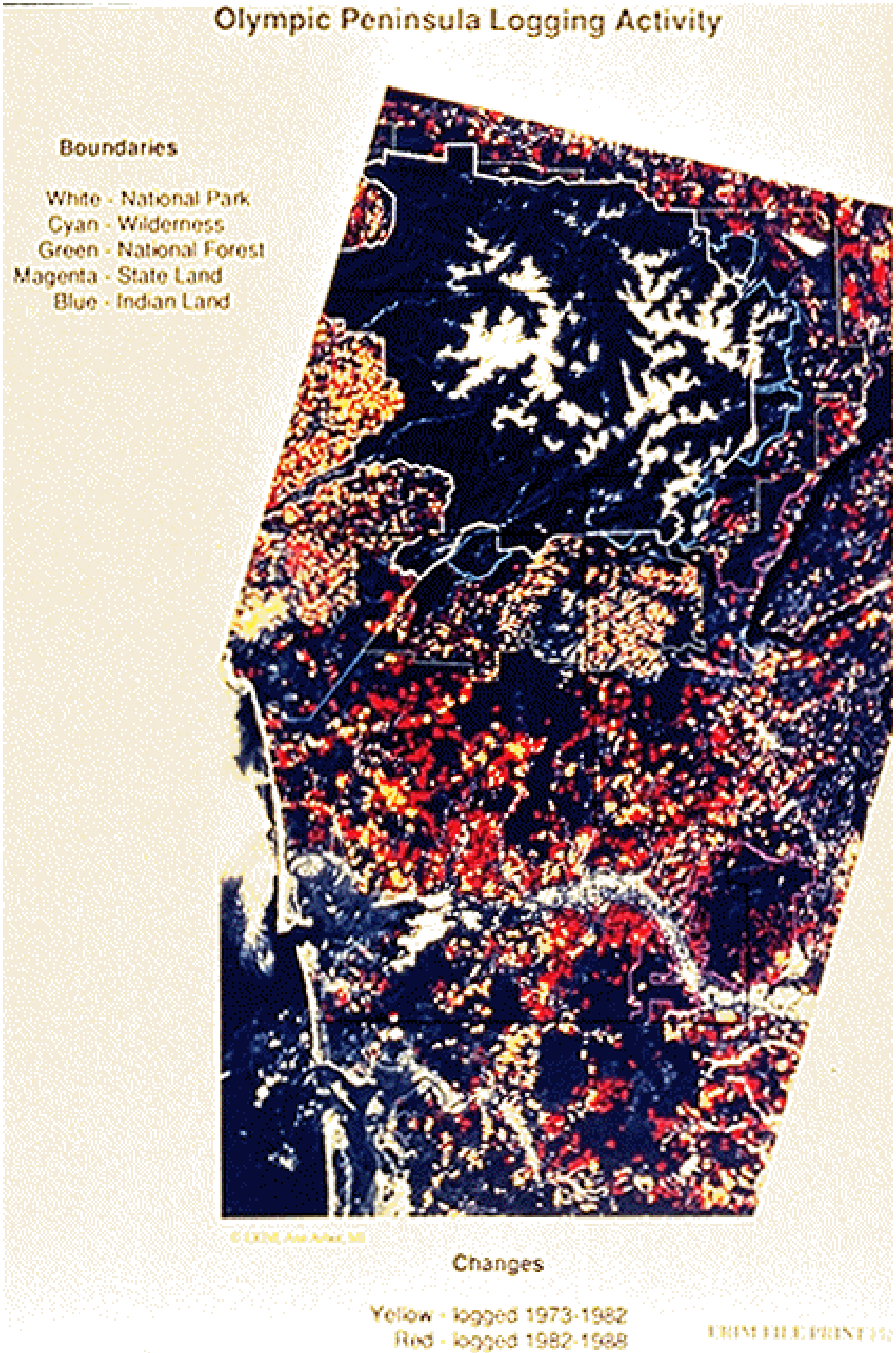
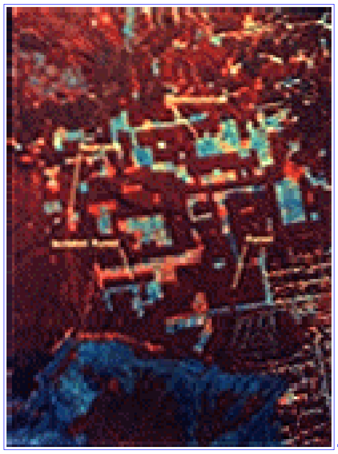


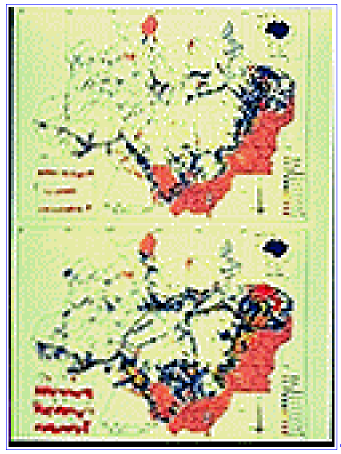

Olympic Peninsula Logging Activity
Boundaries
White - National Park
Cyan - Wilderness
Green - National Forest
Magenta - State Land
Blue - Indian Land
Changes
Yellow - logged 1973-1982
Red - logged 1982-1988

The Earth Observing System Educators' Visual Materials

ID: 4-07 a,b,c,d

Tropical Deforestation and Habitat Degradation In the Brazilian Amazon Basin[1]


4-07a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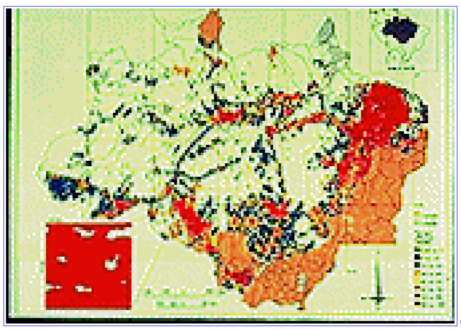
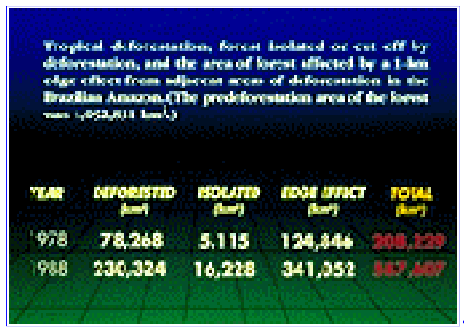

4-07c



4-07d

The Brazilian Amazon is the largest continuous region of tropical forest in the world, containing nearly 31 percent of the world total. Tropical deforestation is a major component of the carbon cycle and has profound implications for biological diversity. Deforestation increases atmospheric carbon dioxide (CO_2) and other trace gases, possibly affecting climate. Conversion of forests to cropland and pasture results in a net flux of carbon to the atmosphere because the concentration of carbon in forests is higher than that in the agricultural areas that replace them. Furthermore, while occupying less than 7 percent of the terrestrial surface, tropical forests provide homes to half or more of all plant and animal species. The primary adverse effect of tropical deforestation is massive extinction of species including, for the first time, large numbers of vascular plant species.

Deforestation affects biological diversity in three ways: (1) destruction of habitat, (2) isolation of fragments of formerly contiguous habitat, defined as areas of less than 100 square kilometers surrounded by deforestation, and (3) edge effects within a boundary zone between forest and deforested areas, defined as 1 kilometer into the forest from adjacent areas of deforestation. In the boundary zone there are greater exposure to winds; dramatic micrometeorological differences over short distances; easier access for livestock, other nonforest animals, and hunters; and a range of other biological and physical effects. The result is a net loss of plant and animal species in the edge areas. Spatial analysis of the geometry of deforestation is critical to the estimation of forest isolation and the edge effect. If 100 km^2 of tropical deforestation occurs as a 10 km by 10 km square and we assume that the edge effect is 1 km, the total area affected is approximately 144 km^2. In contrast, if the 100 km^2 of deforestation is distributed as 10 strips, each 10 km by 1 km, the affected area is approximately 350 km^2.

An analysis of change over a 10-year period of the entire Brazilian Amazon area was performed using Landsat data. For 1988, 210 black and white photographic images from the 1.55-to-1.75 micrometer channel of the Landsat Thematic Mapper, with a ground resolution of about 30 meters, were obtained. The deforested areas were digitized with visual deforestation interpretation and standard vector geographic information system (GIS) techniques. Image 4-07a is a Landsat Thematic Mapper color composite image of southern Rondonia state, Brazil, and illustrates this type of analysis. Taken on June 5, 1988, this image shows areas of tropical forest, deforestation, regrowth, and isolated forest. The area labeled as "isolated forest" is about 3 km by 15 km in size.

To determine the extent of deforestation in 1978, maps produced from single (visible) channel Landsat Multispectral Scanner (MSS) data were digitized. The ground resolution of the MSS channel was about 80 meters. Image 4-07b shows the distribution of deforestation in the Amazon Basin for 1978 (top) and 1988 (bottom). The data were averaged into 16-km-by-16-km grid cells, an example of which is shown in each figure. The broad areas in the east and south, color-coded brown, indicate "cerrado" or savanna (tropical grassland containing scattered trees and drought resistant undergrowth). Image 4-07c shows where biological diversity was adversely affected in 1988 by deforestation, isolation of forest, and the 1-km edge effect from adjacent areas of deforestation. The affected-habitat data were averaged into 16-km-by-16-km grid cells.

The numerical results of the analysis are shown in 4-07d. Deforestation increased between 1978 and 1988 (78,000 to 230,000 km2) as did the total affected habitat (208,000 to 588,000 km2). About 5.6 percent (230,324/4,092,831) of closed canopy forest had been cleared as of 1988 and about 14.4 percent (587,604/4,092,831) of the forested. Amazon was affected by deforestation-caused habitat destruction, habitat isolation, and edge effects. The preponderance of affected habitat results from proximity to areas of deforestation (approximately 341,000 km^2 for a 1-km edge-effect) and not from isolation of forest (approximately 16,000 km^2) or deforestation per se (approximately 230,000 km2). While the rate of deforestation averaged approximately 15,000 km^2/year [(230,324 - 78,268)/10] in the Brazilian Amazon from 1978 to 1988, the rate of habitat fragmentation and degradation was approximately 38,000 km^2/year [(587,604 - 208,229)/10]. Implications for biological diversity are not encouraging and provide added impetus for the minimization of tropical deforestation in the future.

MTPE's future plans include continuing analyses using data from such instruments as the Enhanced Thematic Mapper (ETM), scheduled for flight on Landsat-7, and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by Japan and scheduled for flight on an EOS satellite.

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The Earth Observing System Educators' Visual Materials

ID: 4-05

Biomass Burning

Biomass Burning

This image shows the effects of the burning of trees and other vegetation (known as biomass burning) that takes place when natural forests are cleared for agricultural activities. Typically, a primary forest is cut and allowed to dry for 1-to-4 months. Then the area is burned to remove the woody material and the plant cover to facilitate planting of agricultural crops. After several cycles of planting and burning the productivity of the land is severely decreased until it will support only cattle and pasture.

Deforestation affects the soil and local climate by reducing the evaporative cooling that takes place both from soil and from plant life. As a result, temperatures rise, leading to increased soil erosion and thus increased runoff of rainfall.

At the regional level, the habitat provided by the forest canopy is fragmented by deforestation. Consequently, the species diversity of tropical plant and animal communities in deforested areas is decreasing. Moreover, the aquatic environments in deforested areas have become toxic due to runoff from mining and hydroelectric industries in those areas.

Deforestation can affect both regional and global climate. One consequence of biomass burning is the release of tiny smoke particles that diffuse into the atmosphere, traveling long distances before settling back to the surface. These particles, called aerosols, can change the amounts of solar radiation reaching the Earth's surface and also return radiation from the Earth back to the surface. This combination of effects can change global temperatures. The smoke particles also can serve to increase the number of droplets in clouds, thereby changing the way that clouds reflect or transmit radiation coming from the sun and from the Earth's surface. It has been estimated that the net effect of these smoke particles is to cause some slight cooling at the Earth's surface. Additionally, gas emissions from biomass burnings add to the amount of greenhouse gases in the atmosphere, which can affect global climate.

The observational capabilities and scientific studies planned as part of the MTPE and EOS Programs will help to assess the impact of deforestation on the global climate system.

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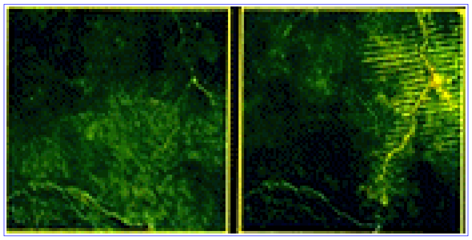
The Earth Observing System Educators' Visual Materials

ID: 4-06

Brazilian Deforestation


Brazilian Deforestation

These Landsat images of the state of Rondonia Brazil were taken in 1975 (left) and 1986 (right). Rondonia experienced a rapid growth in population during that period due to immigration from surrounding states. Settlers, typically, colonized the region adjacent to the main highway to take advantage of the cheap land offered by the government for agricultural development. Areas where forest lands were converted to agricultural uses are easily identifiable as a fishbone pattern radiating from the spine of the highway in the 1986 image.

The contrast between the two images indicates the magnitude of the change that occurred in only 11 years. By comparing satellite images such as these, NASA researchers have shown that 24,000 square kilometers have been converted from forest to agriculture in Rondonia. According to satellite-based estimates, about 5.6 percent of the Brazilian Amazon Basin had been deforested by the end of 1988.

MTPE's future plans include continuing analyses using data from such instruments as the Enhanced Thematic Mapper (ETM), scheduled for flight on Landsat-7 and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by Japan and scheduled for flight on an EOS satellite.

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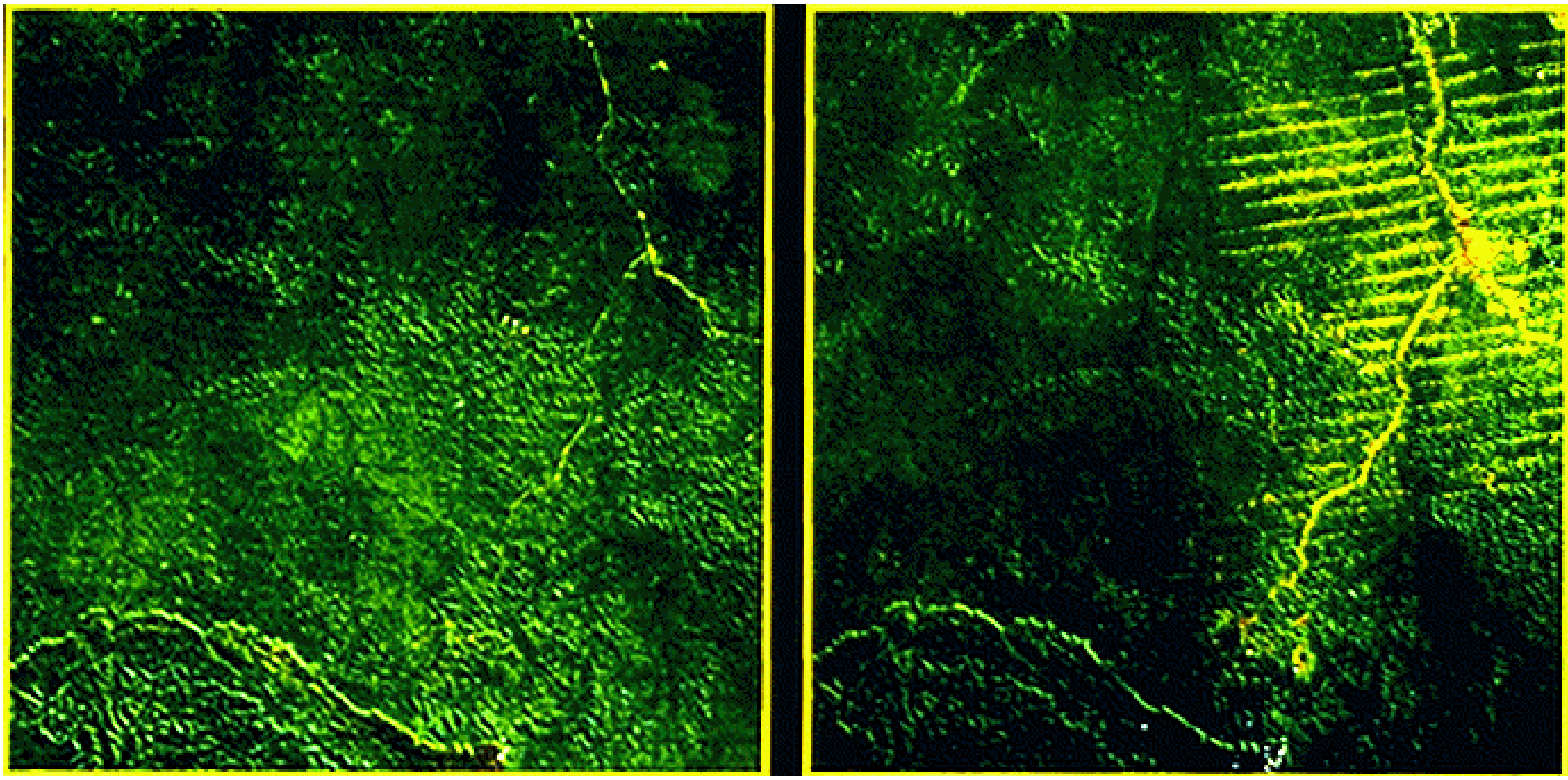
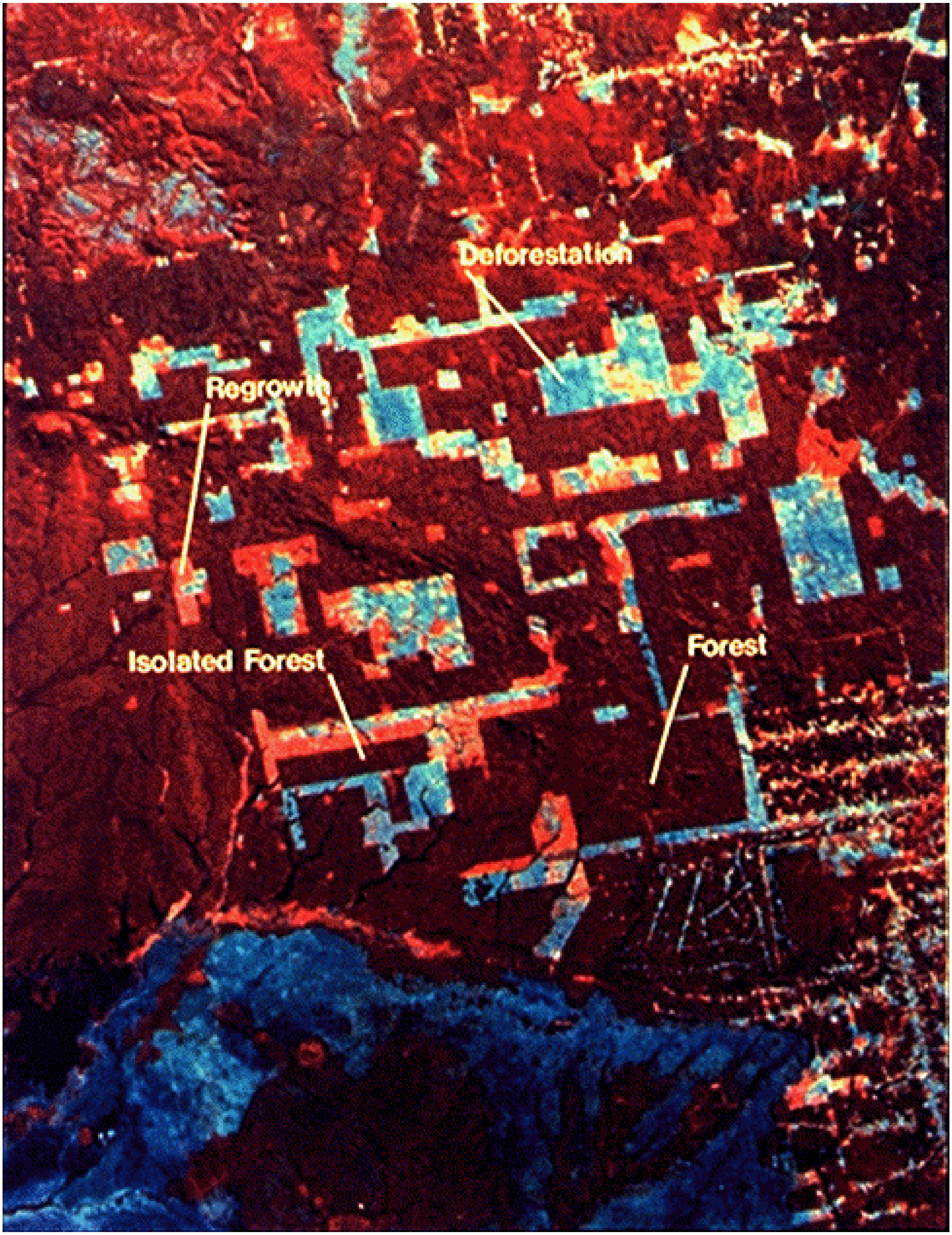
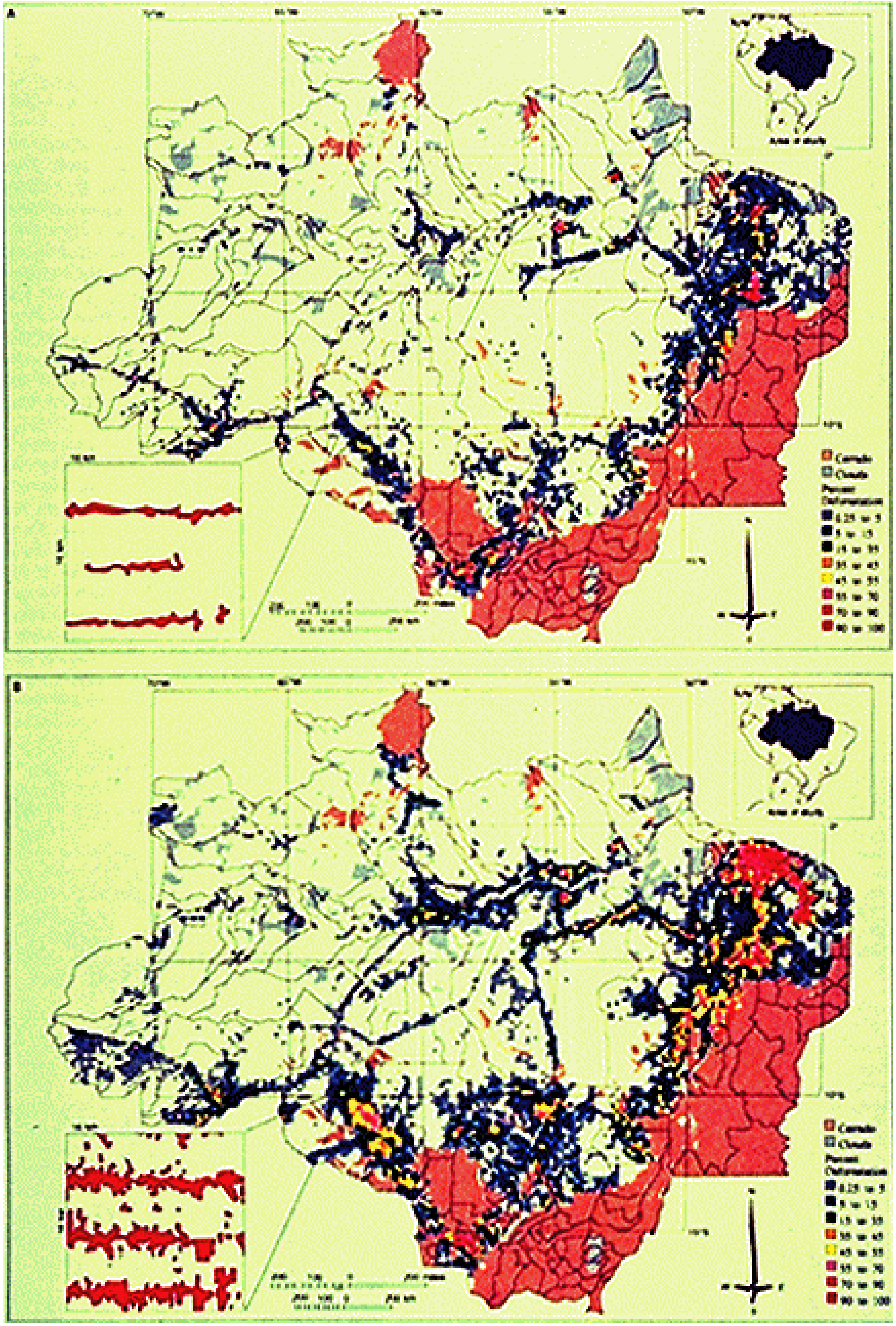
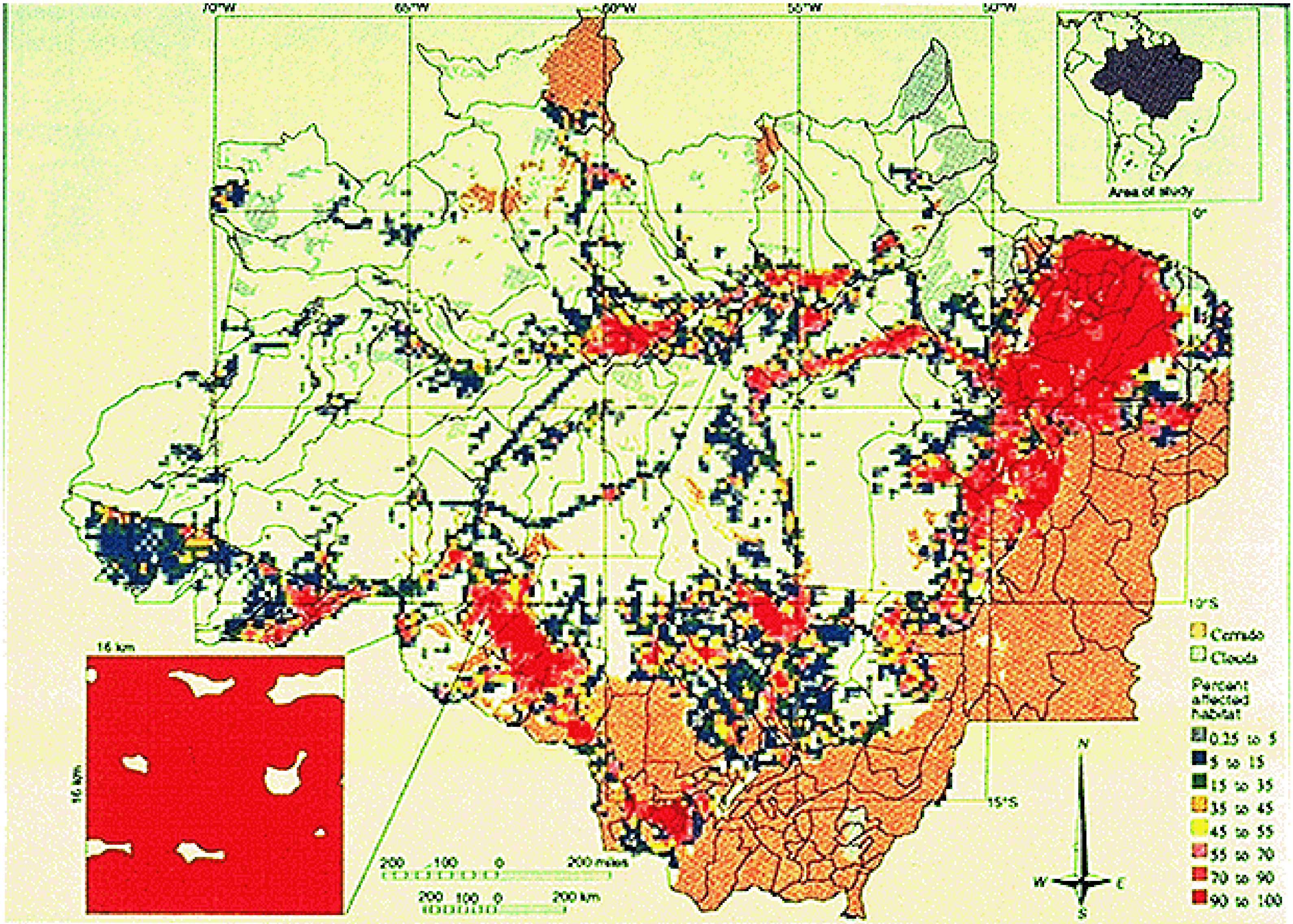



Deforestation
Regrowth
Isolated Forest
Forest




70°W
65°W
60°W
55°W
50°W
Area of study
0°
10°S
15°S
Cerrado
Clouds
Percent affected habitat
0.25 to 5
5 to 15
15 to 35
35 to 45
45 to 55
55 to 70
70 to 90
90 to 100
16 km
16 km
200 100 0 200 miles
200 100 0 200 km
N
W
E
S

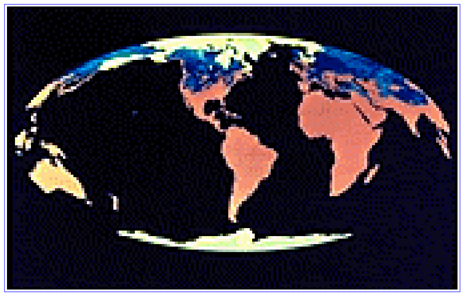
Tropical deforestation, forest isolated or cut off by deforestation, and the area of forest affected by a 1-km edge effect from adjacent areas of deforestation in the Brazilian Amazon. (The predeforestation area of the forest was 4,092,831 km^2.)

YEAR	DEFORESTED (km^2)	ISOLATED (km^2)	EDGE EFFECT (km^2)	TOTAL (km^2)
1978	78,268	5,115	124,846	208,229
1988	230,324	16,228	341,052	587,607

The Earth Observing System Educators' Visual Materials

ID: 5-01

Global Snow and ice cover



Global Snow and ice cover

This image uses a mosaic of data from the Scanning Multichannel Microwave Radiometer (SMMR) on NASA's Nimbus-7 satellite to depict the amount of global snow and ice coverage. Blues ranging from light to dark indicate snow depths ranging from deep to thin. Sea ice is white, and glacier ice is purple. Areas not covered by snow are brown.

The snow pack is monitored by measuring the microwave radiation emitted and scattered by snow. Different snow conditions are associated with different microwave signals, which are received by satellite instruments like the SMMR.

Information about snow cover is important for a number of agricultural, industrial, social, and environmental reasons. For example, snow cover data are needed to predict water supply, to plan for agricultural and industrial developments, to anticipate flooding, to forecast crop yield, and to estimate freeze damage.

Satellite data on snow cover also provide insights about regional climate and geography that have been used to develop military and foreign policy strategies.

Moreover, the amount and depth of snow cover affect climate on a regional and global scale. When snow is deposited on a land surface, it typically increases the degree to which the surface reflects incoming solar energy. In so doing, snow affects the Earth's radiation balance (the balance between energy coming into and leaving the Earth's climate system) and, in turn, its climate. By gaining more accurate information about the properties and effects of snow cover, scientists hope to develop more-accurate models to help them understand and predict the role of snow in the Earth's climate.

The Special Sensor Microwave/Imager (SSM/I) on board Defense Meteorological Satellite Program (DMSP) satellites continues to provide similar information, as will the Multifrequency Imaging Microwave Radiometer (MIMR) developed by the European Space Agency and scheduled for flight on the EOS satellites.

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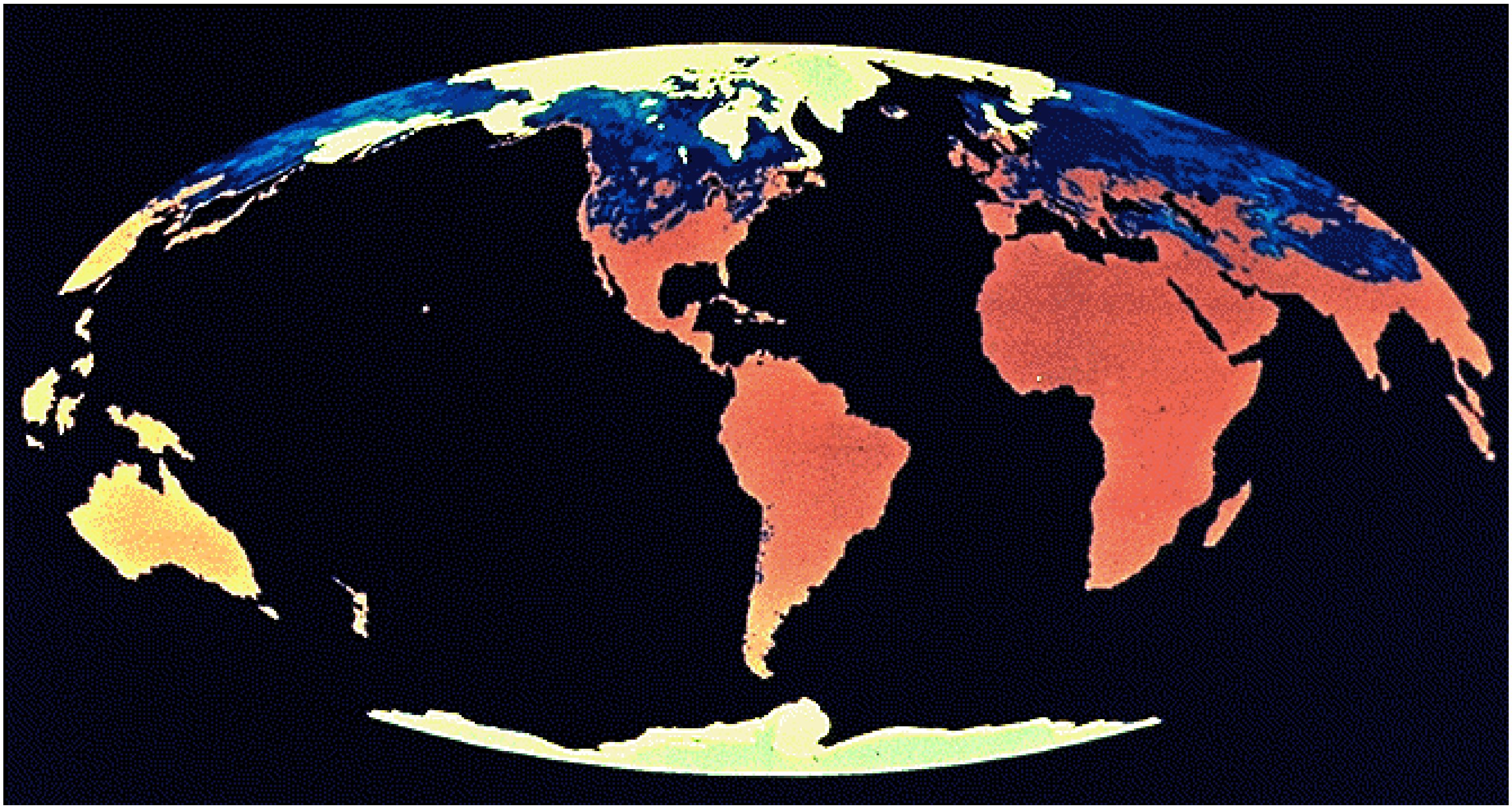
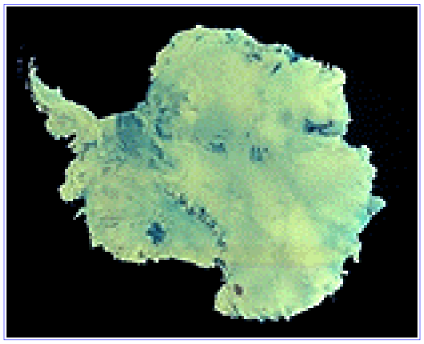


The Earth Observing System Educators' Visual Materials

ID: 5-02

Antarctic Ice Sheet



Antarctic Ice Sheet

The Earth's polar ice sheets, which cover most of Greenland and Antarctica, contain about 77 percent of the world's fresh water. If these ice sheets were to melt, sea level would rise worldwide and flood hundreds of coastal cities. Even small changes in global ice sheets can have serious effects on global sea level and, therefore, coastal regions over several decades.

This image of Antarctica is from data collected by the Advanced Very High Resolution Radiometer (AVHRR) on a NOAA satellite and represents the first complete view of the continent from space. Surface temperatures on the continent vary from warmer, lower regions (in shades of pink) to colder, higher regions (in shades of blue).

Temperature records in the Antarctic Peninsula (extreme left of the image) indicate a warming trend over the past few decades. Some scientists are concerned that the West Antarctic ice sheet, which lies between the Antarctic Peninsula and the Transantarctic Mountains (lower center of the image), may suddenly increase its discharge of ice into the oceans as a result of the warming. Such an increase would cause rapid increases in sea level.

Scientists are using satellite data to determine whether the Earth's ice sheets are growing or shrinking, and to help them create accurate models to predict what would happen to ice sheets in the event of significant global climate change.

Plans are underway to obtain more-precise measurements of Arctic and Antarctic ice sheets using radar and laser altimeters proposed for flight on the EOS-Altimetry satellites.

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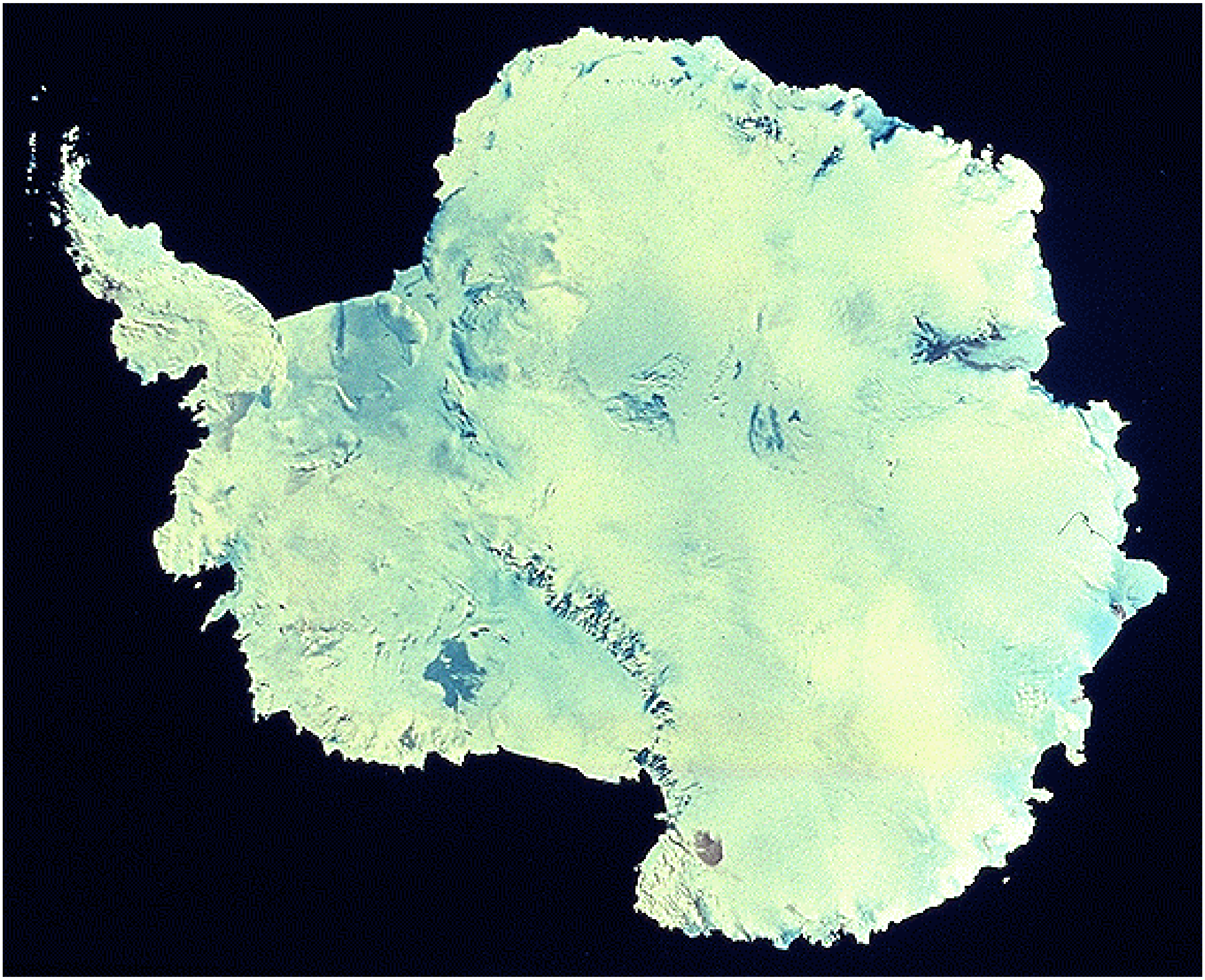
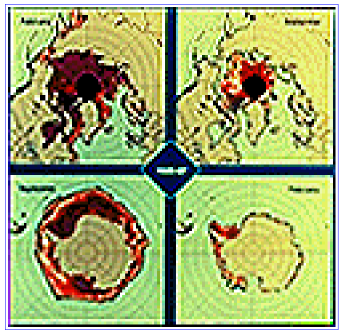


The Earth Observing System Educators' Visual Materials

ID: 5-03

1986-1987 Summer and Winter Sea-Ice coverage for Both Poles.



1986-1987 Summer and Winter Sea-Ice coverage for Both Poles.

Polar sea ice is one of the most variable features of the Earth's climate, changing considerably from summer to winter and from one year to another. At any given time, global sea ice covers an area approximately the size of the North American continent. The presence of the ice restricts the transfer of heat between the ocean and the atmosphere. The ice also restricts evaporation into the atmosphere and affects the circulation of the ocean.

These four images, constructed using data from the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 satellite show the amount of polar sea-ice coverage for September 1986 and February 1987. The top two images are of Arctic ice cover and the bottom two images are of Antarctic ice cover. Late in the Arctic summer (September), sea-ice coverage is at a minimum-approximately 9 million square kilometers in 1986. In the Arctic winter (February) sea-ice coverage reaches a maximumÑabout 15 million square kilometers in 1987. By comparison, the area of the continental United States is 9.5 million square kilometers, while Canada's area is 10 million square kilometers.

The third and fourth images, for the Antarctic region, show a much greater difference in sea-ice coverage between summer and winter. In the late winter/early spring (September in the southern hemisphere), sea ice covered 19 million square kilometers in 1986. In the summer (February), however, Antarctic sea-ice cover shrank to only 4 million square kilometers. A comparison of the areas surrounding each pole reveals the reasons for these differences.

The area at the Arctic pole is ocean, bounded by the continents of the Northern Hemisphere. The continental boundaries, therefore, limit the extent to which sea ice can grow during the cold months. In contrast, sea ice in the southern hemisphere has no "land boundaries" to the north to limit the winter's sea-ice growth.

In the summer, geography again plays a role in sea-ice coverage. At both poles, the coldest region is directly over the pole. In the Arctic, the coldest region is covered by water. Arctic sea ice thus shrinks less in summer because it lies in an area that stays very cold.

The Earth's south pole, on the other hand, is covered by the continent of Antarctica. Sea ice extends from the coast of the continent, which is further away from the extreme cold of the pole. The sea ice therefore lies in a relatively warm climate, causing greater melting during the warm summer months.

Future plans for studying the dynamics of sea-ice coverage include the use of data from the Special Sensor Microwave/Imager (SSM/I), currently on board Defense Meteorological Satellite Program (DMSP) satellites, and data from the European Space Agency's Multifrequency Imaging Microwave Radiometer (MIMR), scheduled for flight on the EOS satellites.

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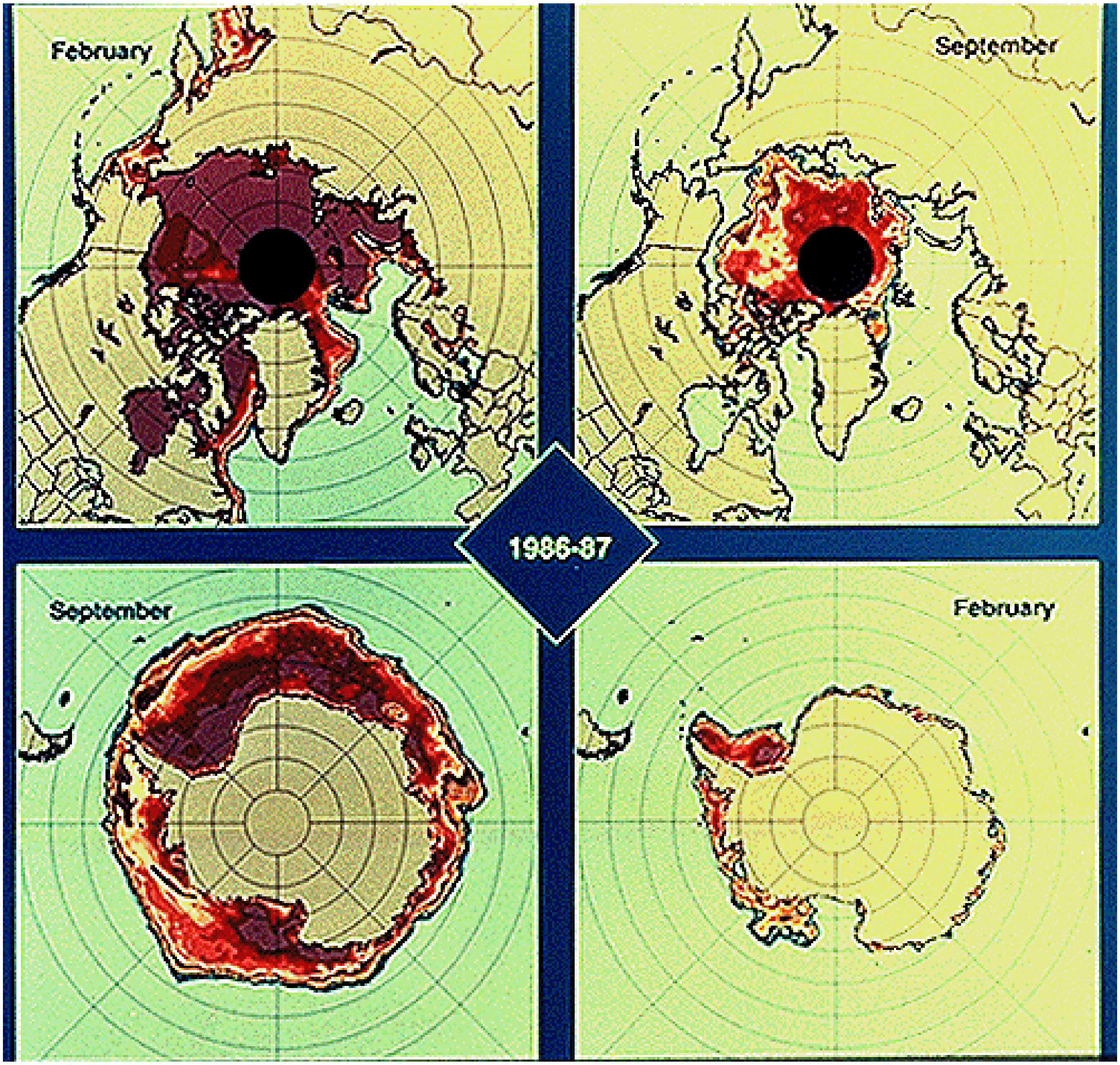
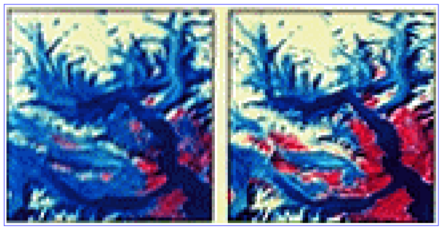

February
September
1986-87
September
February

The Earth Observing System Educators' Visual Materials

ID: 5-04

Retreat of The Muir Glacier



Retreat of The Muir Glacier

These Landsat images, acquired 13 years apart, show the retreat of the Muir Glacier (A) in south-eastern Alaska. Between September 12, 1973 when the image on the left was acquired and September 6, 1986 when the image on the right was acquired, the Muir Glacier retreated to the northwest more than 7 kilometers. Other nearby glaciers have been shrinking over a period of several decades as well. By 1986 the Burroughs Glacier (B) had become a melting ice field, having been cut off from its source of replenishment to the northwest because of glacier shrinkage. Vegetation encroaches quickly as deglaciation occurs. This can be seen when comparing the amount of vegetation (shown in red) in the images.

In the future, routine observation and assesment of changes in glaciers on a global basis will be available from such instruments as the Enhanced Thematic Mapper (ETM), scheduled for flight on Landsat-7, and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), provided by Japan and scheduled for flight on an EOS satellite.

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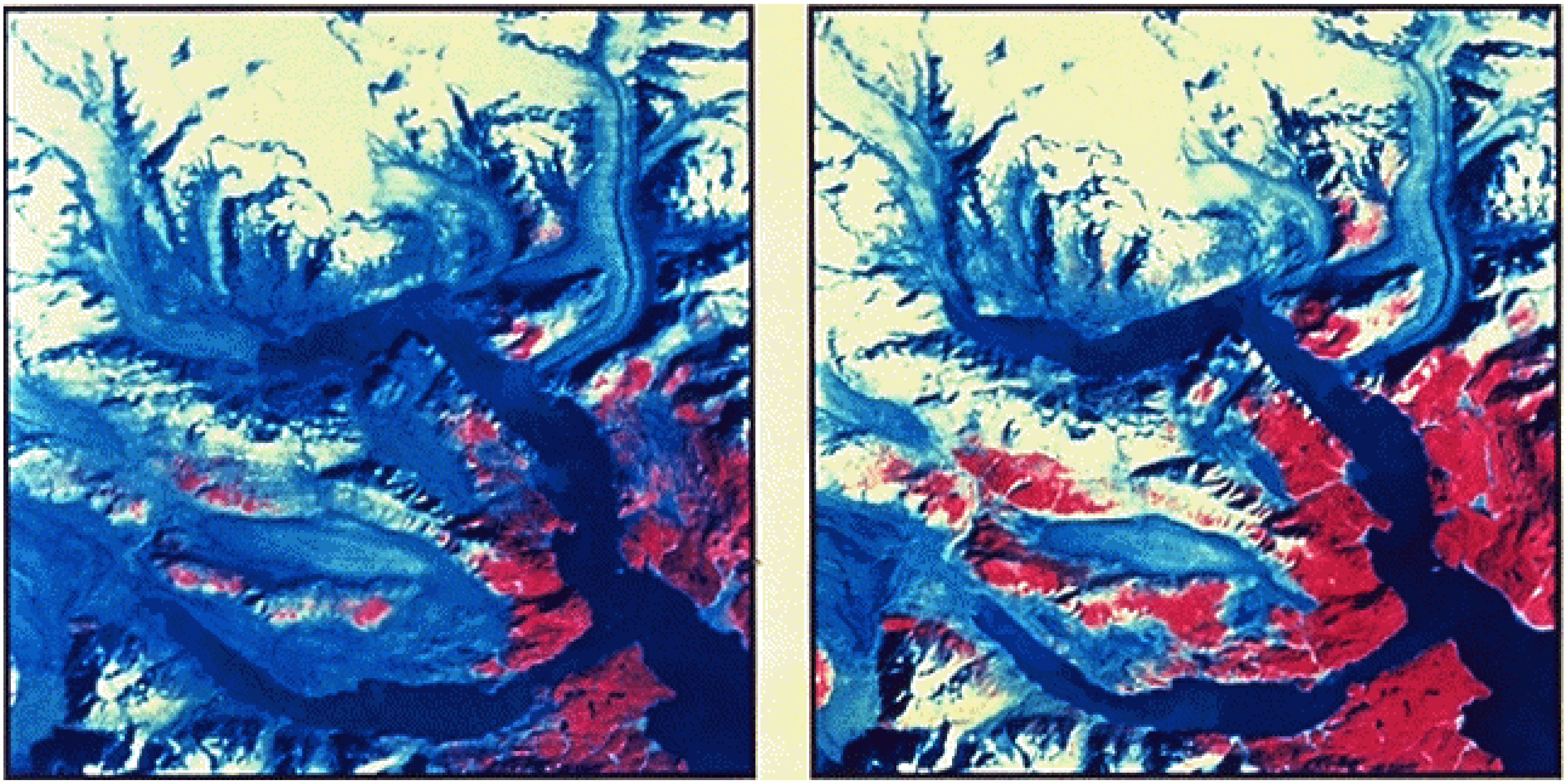
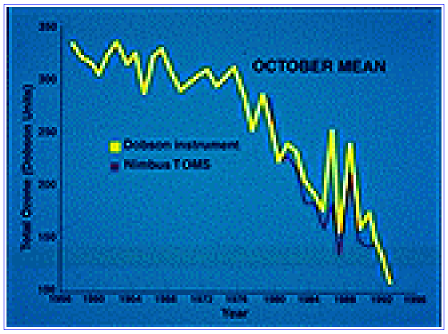


The Earth Observing System Educators' Visual Materials

ID: 6-01

The October "Ozone Hole"Over Antarctica



The October "Ozone Hole"Over Antarctica

A thin layer of ozone in the stratosphere absorbs much of the sun's ultraviolet radiation (UV), thus helping to protect us against skin cancer, cataracts, and damage to our immune systems.

The Total Ozone Mapping Spectrometer (TOMS) instrument, first flown on the Nimbus-7 satellite in October 1978, makes daily, worldwide, observations of the total amount of ozone in the atmosphere, measured on a Dobson scale. [One Dobson unit refers to a layer of ozone that would be 0.001 cm thick under conditions of standard temperature (0 degree C) and pressure (the average pressure at the surface of the Earth). Thus, for example, 300 Dobson units of ozone brought down to the surface of the Earth at 0 degree C would occupy a layer only 0.3 cm thick!] Amounts of ozone can be compared from region to region over huge areas by color coding the measurement units from the Dobson scale. Ozone layer density varies greatly, partly because ozone molecules drift and swirl in cloud-like patterns in the stratosphere (~12-to-50 km above Earth's surface).

TOMS has been measuring ozone concentrations since 1979. However, scientists have been measuring ozone since the 1920's with "Dobson" instruments at ground level. The amount of UV radiation that gets through the atmosphere is used to calculate the concentration of ozone in the atmosphere above a given location. Ground-based measurements have been made since 1956 at Halley Bay, Antarctica. The figure shows that the October (springtime) ground-based mean measurements correlate well with the satellite data from TOMS.

The springtime decline in total ozone over Antarctica produces what is widely known as the "ozone hole." As summer approaches, the total ozone increases and the "hole" disappears.

Stratospheric clouds over Antarctica contain ice particles not found at warmer latitudes. Reactions occurring on the surface of the ice particles speed the ozone destruction caused by chlorine atoms from industrial chemicals, mainly the chlorofluorocarbons (CFCs) used in refrigeration and other applications.

The figure also shows that there is a general, continuing decline in the amount of ozone present during the October period of the annual "ozone hole."

A continuing ozone monitoring program is underway using TOMS. A TOMS instrument was flown on a Russian Meteor-3 satellite in 1991, another TOMS is scheduled for flight on the Japanese Advanced Earth Observing Satellite-1 (ADEOS-1) and several EOS small satellites.

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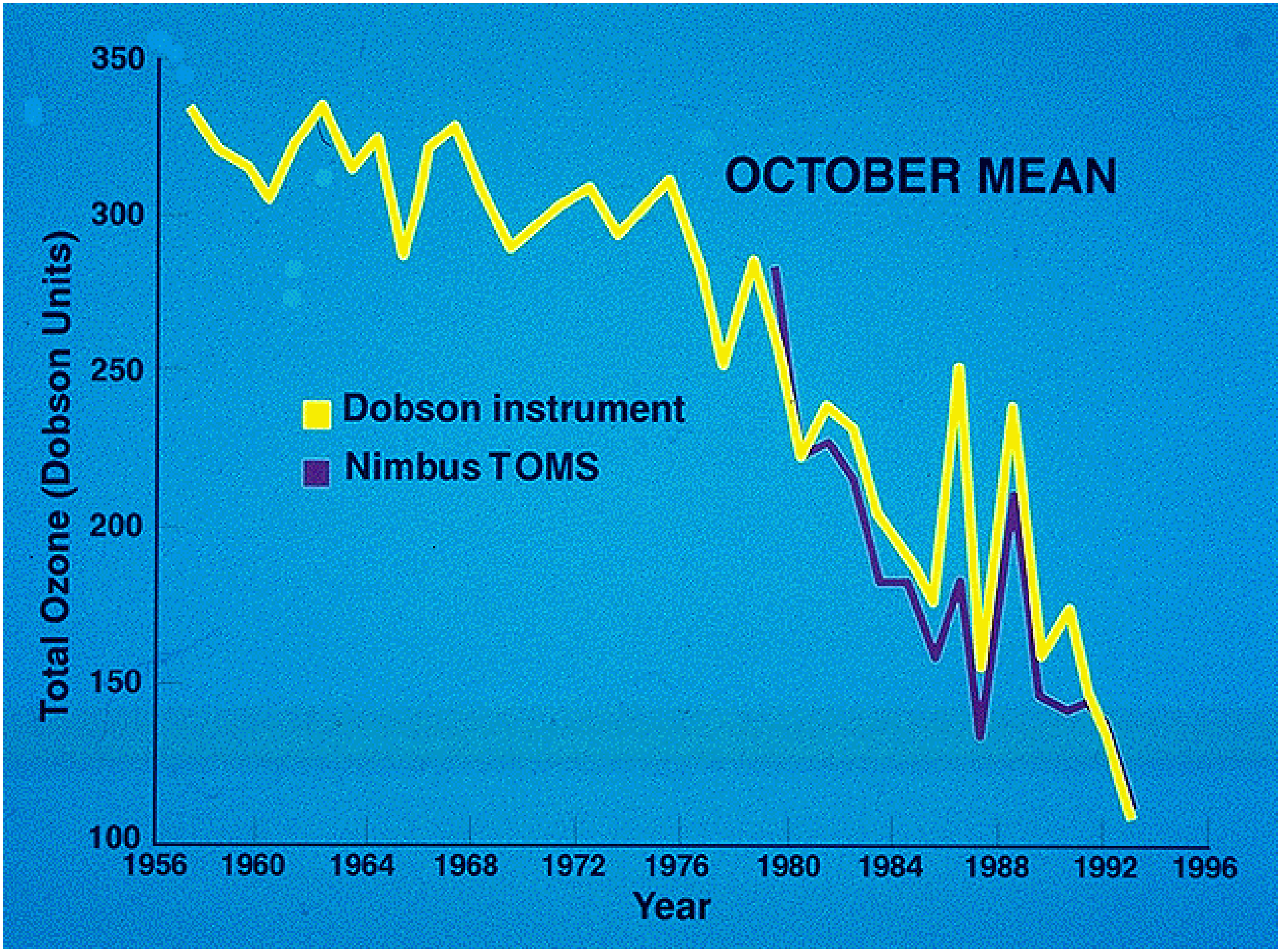
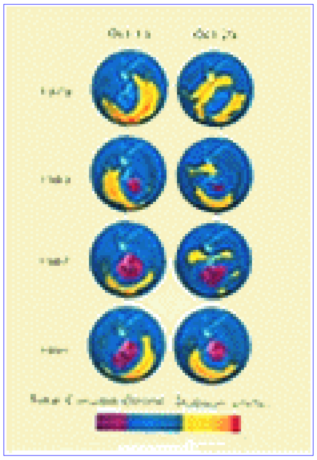

OCTOBER MEAN
Dobson instrument
Nimbus TOMS
Total Ozone (Dobson Units)
350
300
250
200
150
100
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
Year

The Earth Observing System Educators' Visual Materials

ID: 6-02

Changes in Springtime Ozone over Antarctica, October Comparisons, 1979-1991



Total column Ozone (Dobson units)

Refer to ID: 6-01 for introductory material.

Stratospheric clouds over Antarctica contain ice particles not found at warmer latitudes. Reactions occur on the surface of the ice particles and speed the ozone destruction caused by chlorine atoms from industrial chemicals, mainly the chlorofluorocarbons (CFCs) used in refrigeration and other applications.

The springtime decline in total ozone over Antarctica produces what is widely known as the "ozone hole". As summer approaches the ozone increases and the "hole" disappears.

These images, obtained by NASA's TOMS instrument, compare the springtime (October) changes in ozone concentrations over Antarctica. The color-coded global images from 1979 to 1991 depict and compare the total amount of ozone over Antarctica in a column of atmosphere from the ground to the top of the ozone layer.

For each year, two images are shown, indicating that the phenomenon is not ephemeral but rather extends over a period of many weeks. The size and shape of the hole vary from year to year, but it is a cohesive unit that does not fragment. Also, the location of the hole varies, suggesting that it may be moved about by winds or other atmospheric conditions.

The images clearly show that since 1979, the protective ozone layer has declined in concentration and area. In fact, the ozone hole has grown so much over the years that it now is about the size of the entire Antarctic continent.

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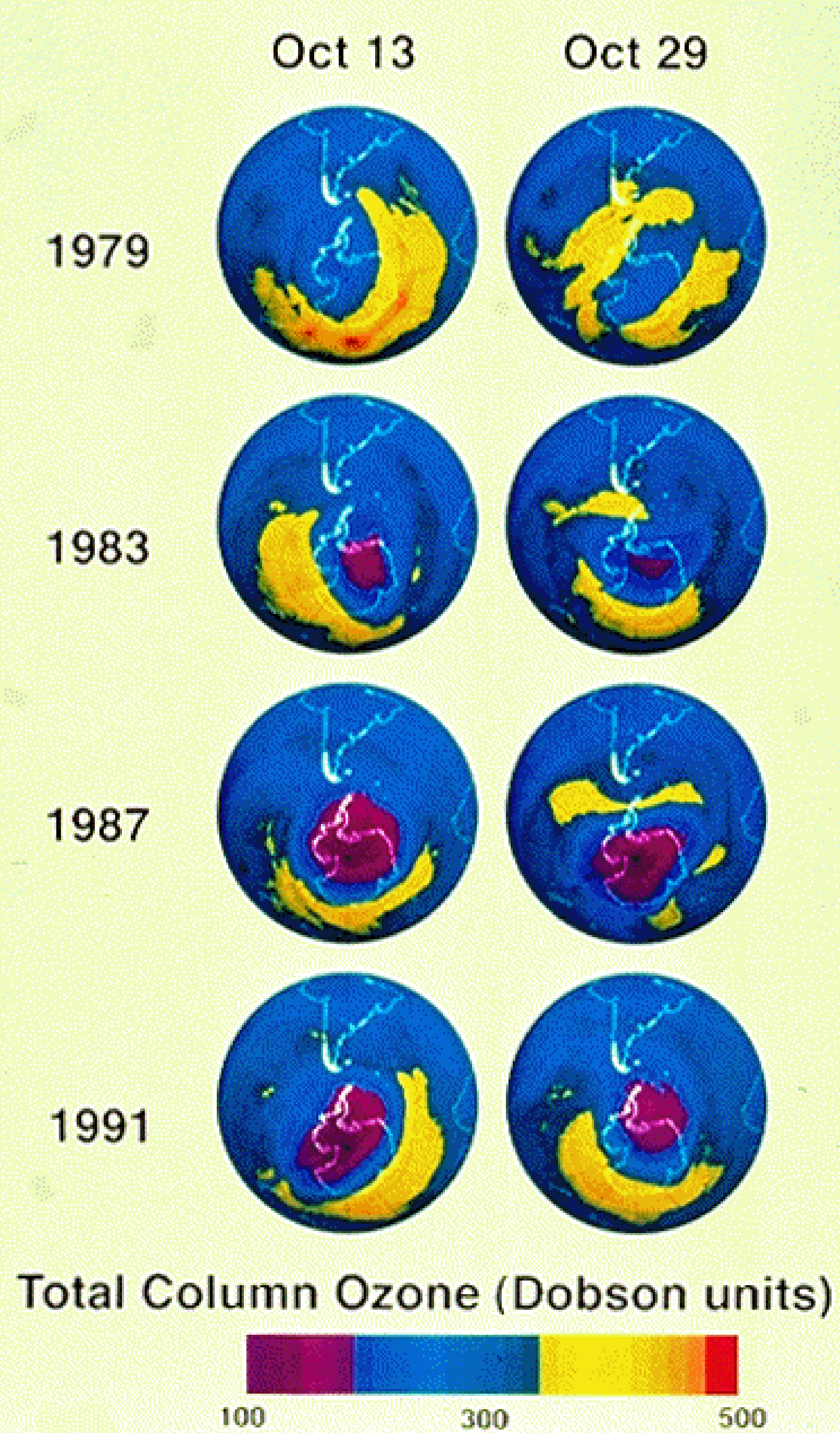
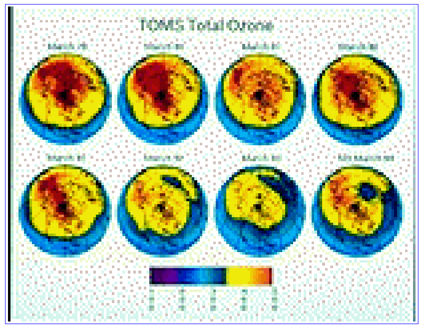

Oct 13
Oct 29
1979
1983
1987
1991
Total Column Ozone (Dobson units)
100
300
500

The Earth Observing System Educators' Visual Materials

ID: 6-03

Eight "Marches" in the Northern Hemisphere



Eight "Marches" in the Northern Hemisphere

Refer to ID: 6-01 for introductory material.

Data from NASA's TOMS instrument show an ozone decline in the northern hemisphere from the late 1970's to the early 1990's. The slide compares four years of March monthly average readings with a similar period starting 12 years later.

Note that the yellow and red colors (high ozone values) are not present in the 1993 data (but present in the 1994 data), indicating a reduction of ozone thought to be caused by the Mount Pinatubo eruption. Scientists now are confident that ozone is being depleted worldwide-partly due to the manufactured chemicals called CFCs, or chlorofluorocarbons, used in refrigeration and other applications. Wafted to the stratosphere, CFCs break down under ultraviolet light and release chlorine atoms that attack ozone. Ozone, a relatively unstable molecule made up of three atoms of oxygen, is destroyed when a chlorine atom steals an oxygen atom from it.

Data from the NASA Upper Atmosphere Research Satellite (UARS), launched in 1991, have increased our understanding of the processes that contribute to the depletion of ozone. Also, plans are underway as part of the MTPE Program to launch several instruments on the EOS-Chemistry satellites to continue the study of ozone processes.

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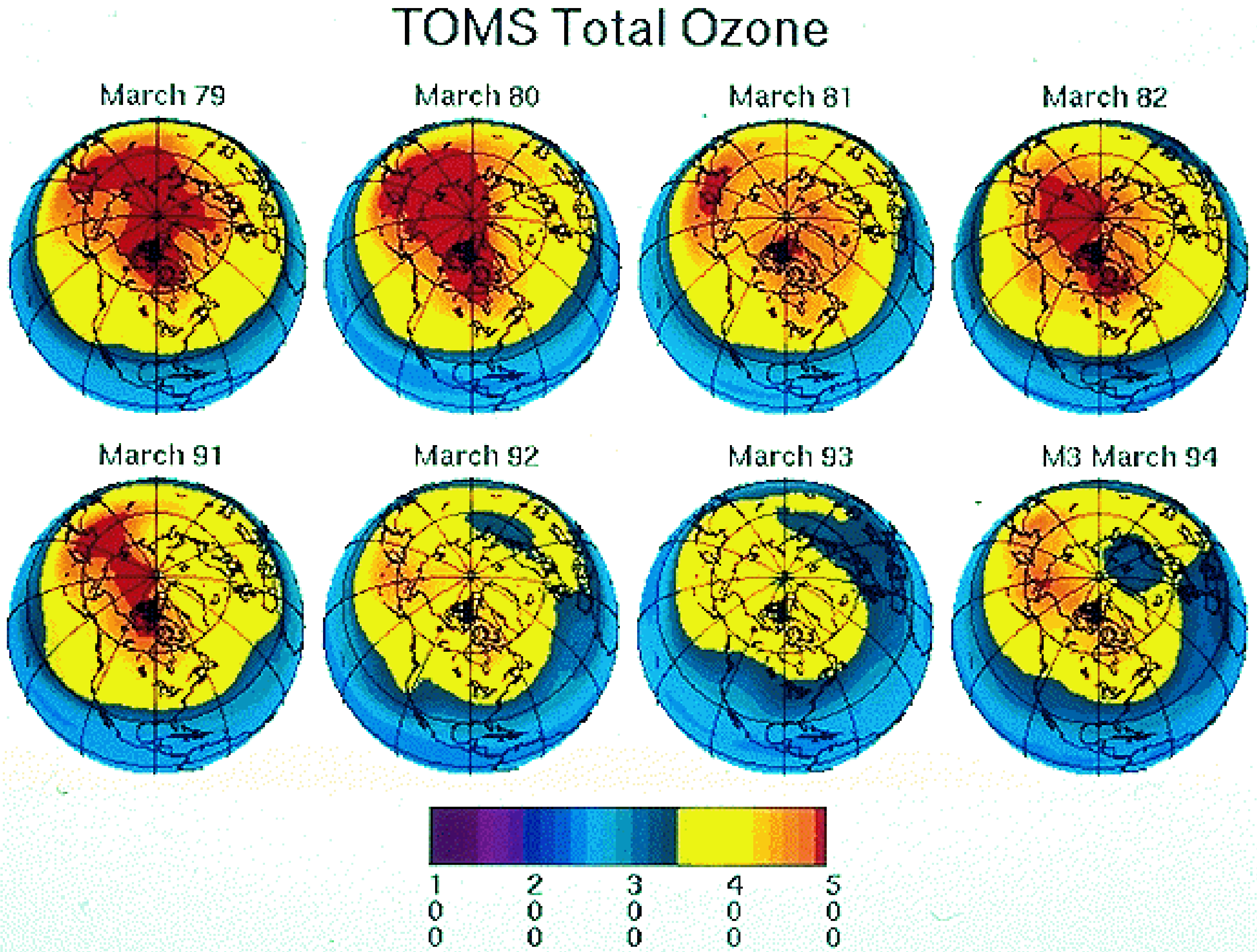
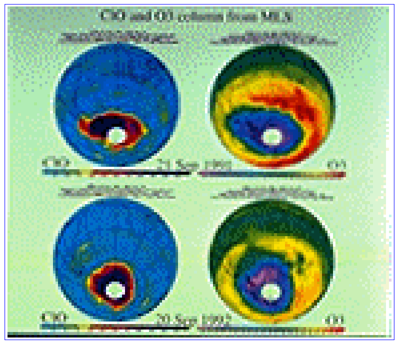

TOMS Total Ozone
March 79
March 80
March 81
March 82
March 91
March 92
March 93
M3 March 94
1
0
0
2
0
0
3
0
0
4
0
0
5
0
0

The Earth Observing System Educators' Visual Materials

ID: 6-04

Ozone Chemistry



CIO and O_3 column from MLS

Chlorine monoxide (ClO), the dominant ozone-destroying chlorine molecule, and ozone were measured in the stratosphere of the Southern Hemisphere in September of 1991 and 1992 by the Microwave Limb Sounder (MLS), flown on the Upper Atmosphere Research Satellite (UARS). The color scales below the images on the left relate to C1O concentrations, ranging from small concentrations (blue), through green and yellow, to large concentrations (red and purple). Large concentrations of C1O are seen over Antarctica. The total-column ozone scales on the right range from violet (120 Dobson units), through blue, green, yellow, and orange, to red (330 Dobson units). Strong ozone minimums over Antarctica are seen on the right, corresponding to the C1O maximums on the left. (However, a simple cause and effect relationship should not be inferred from this figure. Many radiative, chemical, and dynamical processes contribute to the Antarctic ozone minima.)

The sulfur dioxide (SO_2) injected into the stratosphere by a volcano reacts with atmospheric water vapor to form sulfuric acid aerosols, which appear to enhance the ozone depletion resulting from heterogeneous reactions of chlorine species on polar stratospheric clouds. A prime source of the chlorine species is the chlorofluorocarbons (CFCs) used in refrigeration and various manufacturing processes.

The CFCs take part in one of the most-efficient ozone-destroying catalytic cycles in the stratosphere. Briefly, this is how it works. When ultraviolet radiation strikes a CFC molecule, it causes a chlorine atom (Cl) to break away. The chlorine atom collides with an ozone molecule (O_3) and steals an oxygen atom (O) to form chlorine monoxide (ClO) and leave a molecule of ordinary oxygen (O_2). When a free atom of oxygen (O) collides with the ClO, the two oxygen atoms form a molecule of oxygen (O_2), thus leaving the chlorine atom free to destroy more ozone (see page 63).

Total-column ozone amounts for 1992 during the springtime in the Antarctic stratosphere were the lowest ever observed. Some of the enhanced ozone depletion in 1991 and 1992 has been explained as being due to increased ozone destruction in the presence of aerosols from the Pinatubo volcanic eruption. This extreme behavior is expected to be limited to just a few years, during which time the volcanic particles will have been removed from the stratosphere.

Future plans include a Microwave Limb Sounder (MLS) on the EOS-Chemistry satellite.

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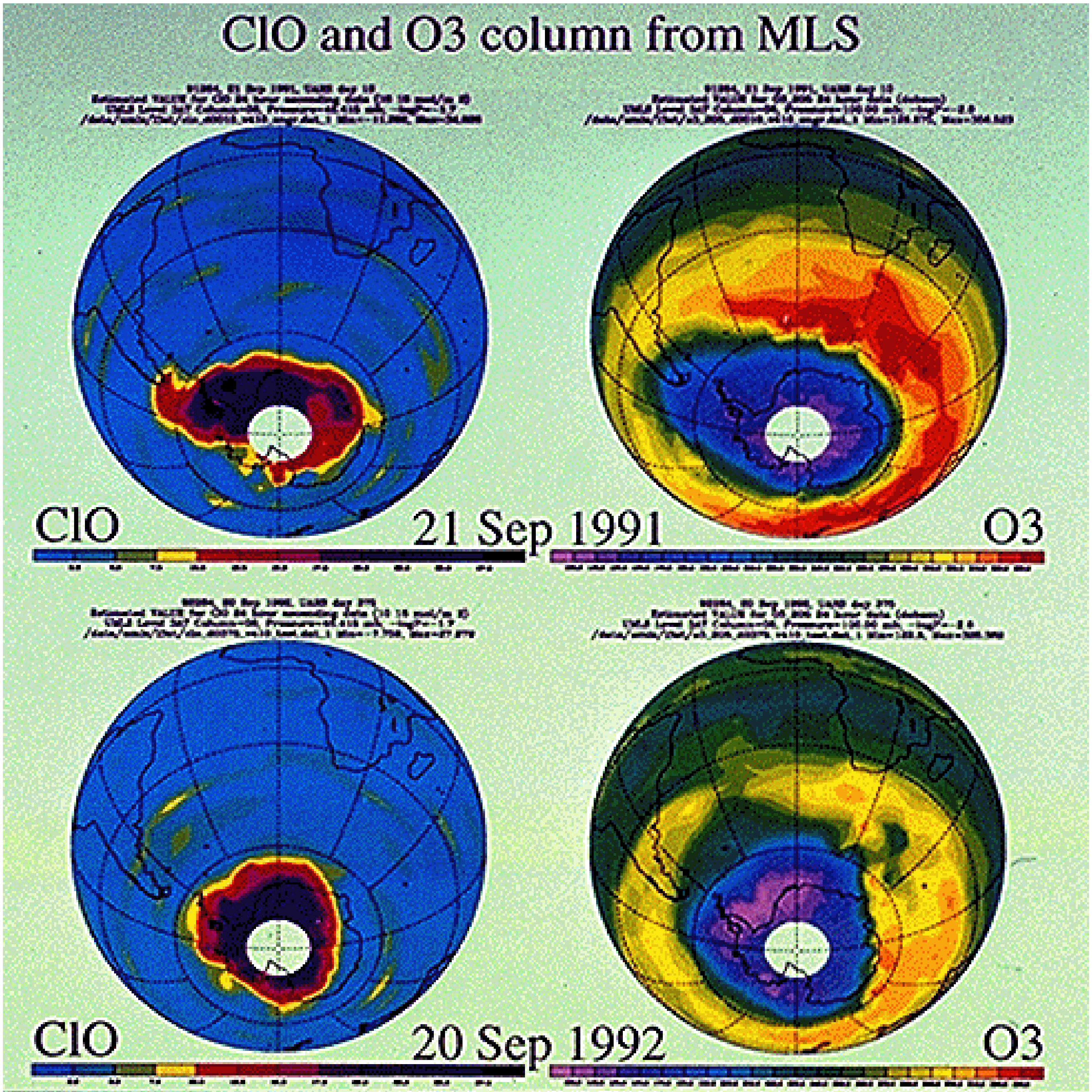
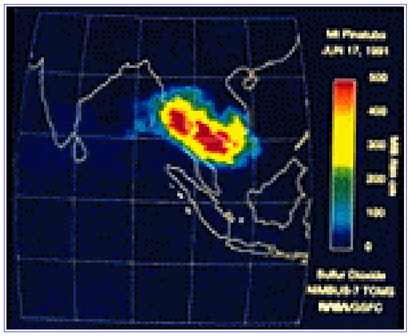

ClO and O3 column from MLS
ClO
21 Sep 1991
O3
ClO
20 Sep 1992
O3

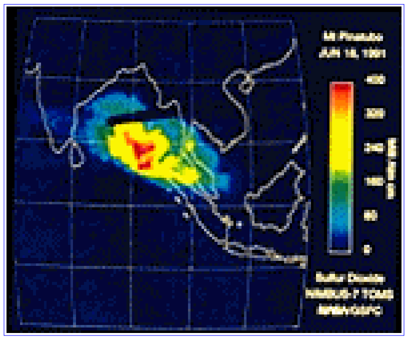
The Earth Observing System Educators' Visual Materials

ID: 7-01 a, b, c

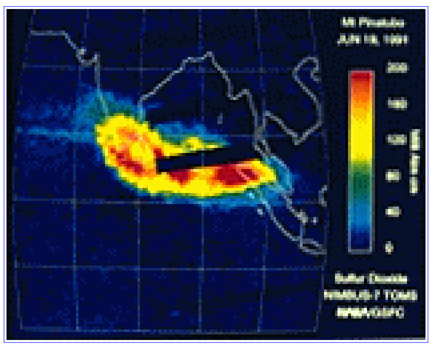
Mount Pinatubo Sulfur Dioxide Cloud (TOMS)



(7-01a. Mt. Pinatubo, June 17, 1991)



(7-01b. Mt. Pinatubo, June 18, 1991)



(7-01c. Mt. Pinatubo, June 19, 1991)

Refer to ID: 6-01 for introductory material.

Volcanoes affect climate because of their ability to inject megatons of sulfur dioxide into the stratosphere. The sulfur dioxide then reacts with water in the stratosphere to form sulfuric acid aerosols, which absorb and reflect incoming radiation from the sun. With less solar radiation reaching the Earth's surface, the climate cools.

The eruption of Mount Pinatubo renewed scientific interest in monitoring global volcanic activity, which can be achieved most comprehensively--and most safely--using satellite observations. The Total Ozone Mapping Spectrometer (TOMS) instrument on board the Meteor-3 satellite provides daily data on sulfur dioxide and ozone concentrations.

Mount Pinatubo, which had no documented activity for over 600 years, erupted on June 15, 1991, spewing approximately 20 million tons of sulfur dioxide into the atmosphere. Image 7-01a, taken on June 17, 1991, shows that the cloud had separated from the volcano and drifted 1200 kilometers to the Gulf of Siam. The leading edge of the cloud then sheared away from the main cloud and drifted over the southern tip of India, traveling 5500 kilometers in 36 hours (as shown in 7-01c).

Images 7-01b and 7-01c, taken June 18 and June 19, 1991 respectively, show the westward progression and gradual dispersion of the massive cloud. On July 7, 22 days after the main eruption, the sulfur dioxide cloud observed by the TOMS instrument had traveled around the entire globe. [Note: The "Milli Atm cm" scale shown on these three images indicates the derived vertical column thickness of sulfur dioxide in units of 0.001 cm at standard temperature (0 degree C) and pressure (the average pressure at the surface of the Earth).]

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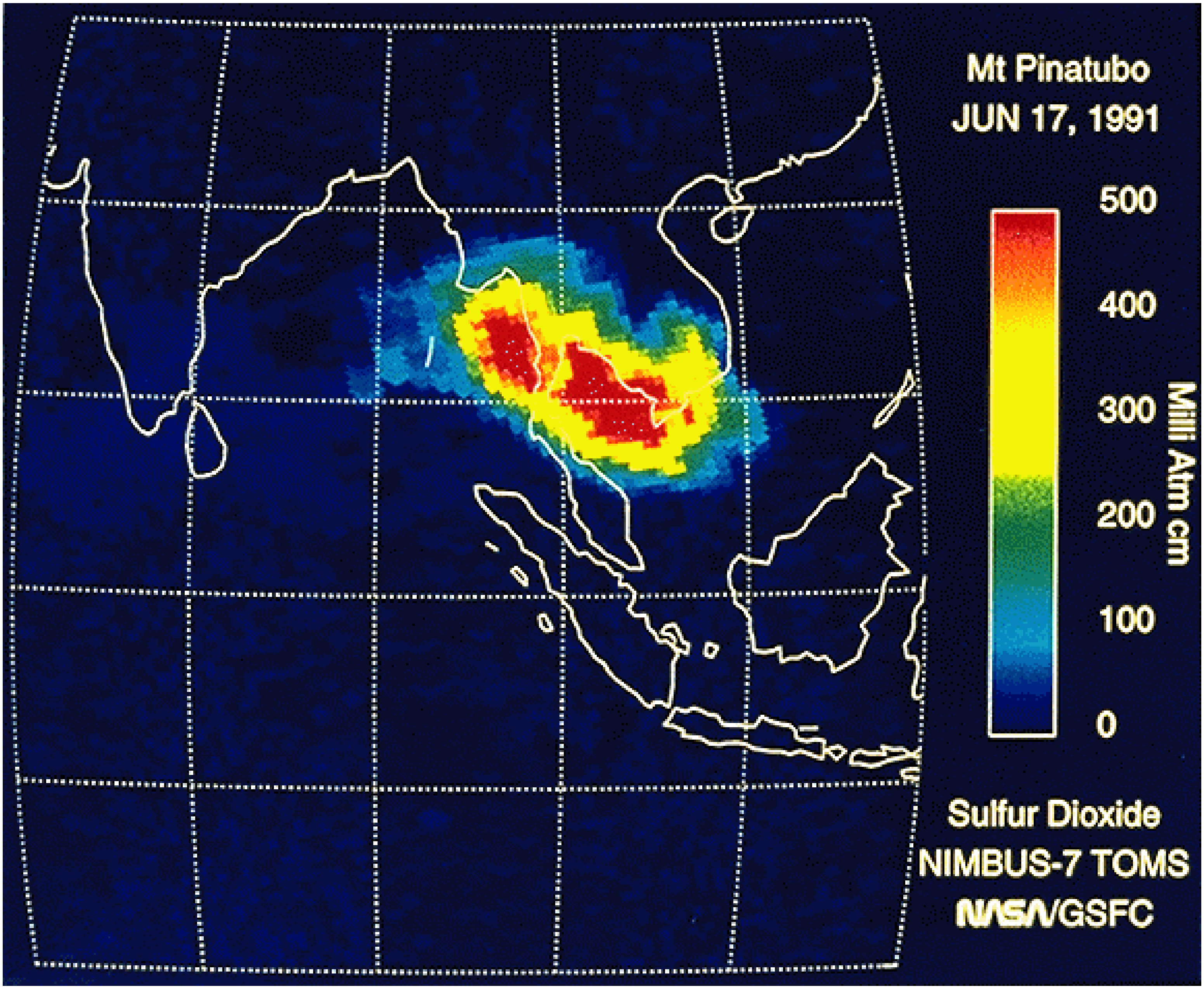
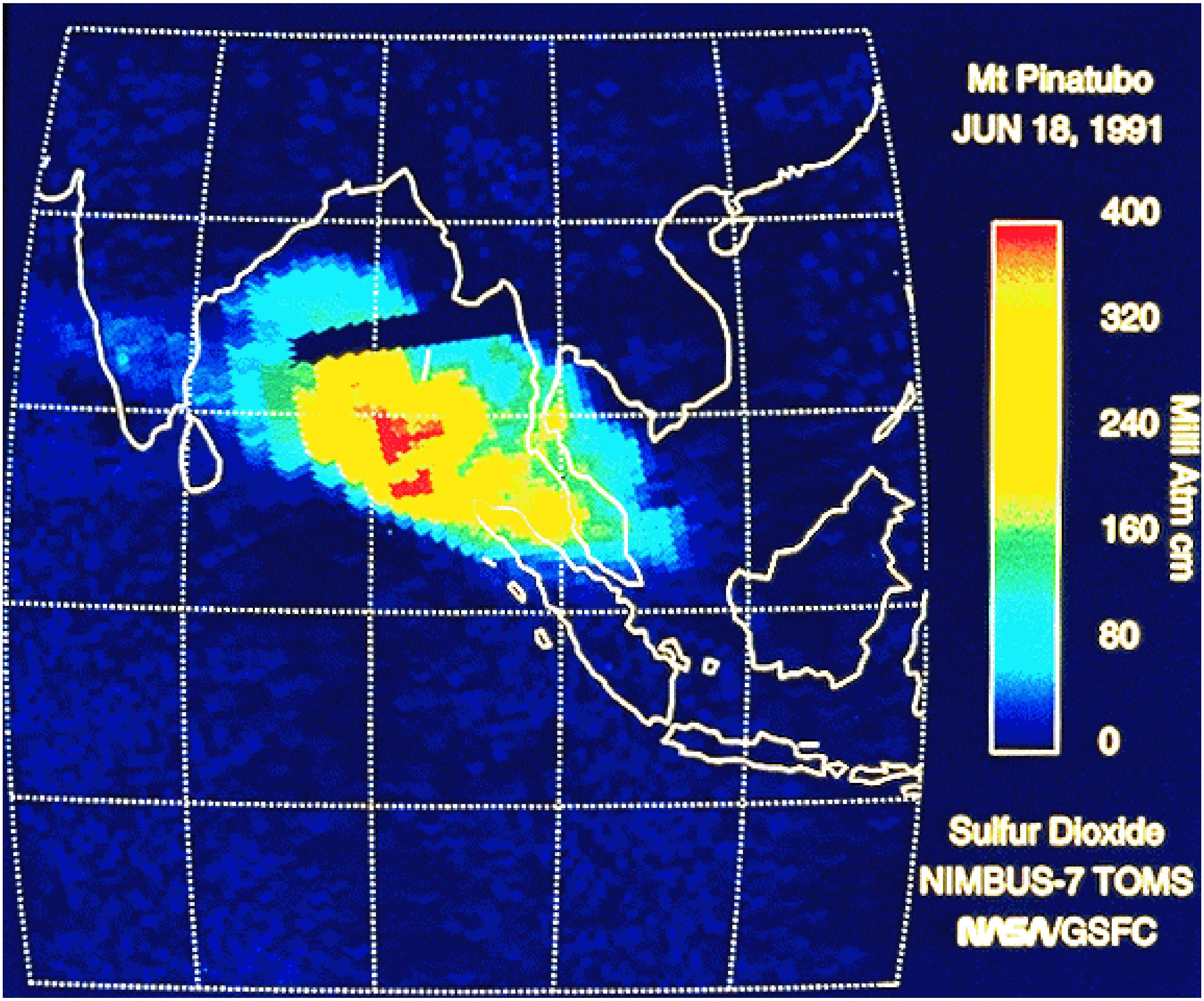
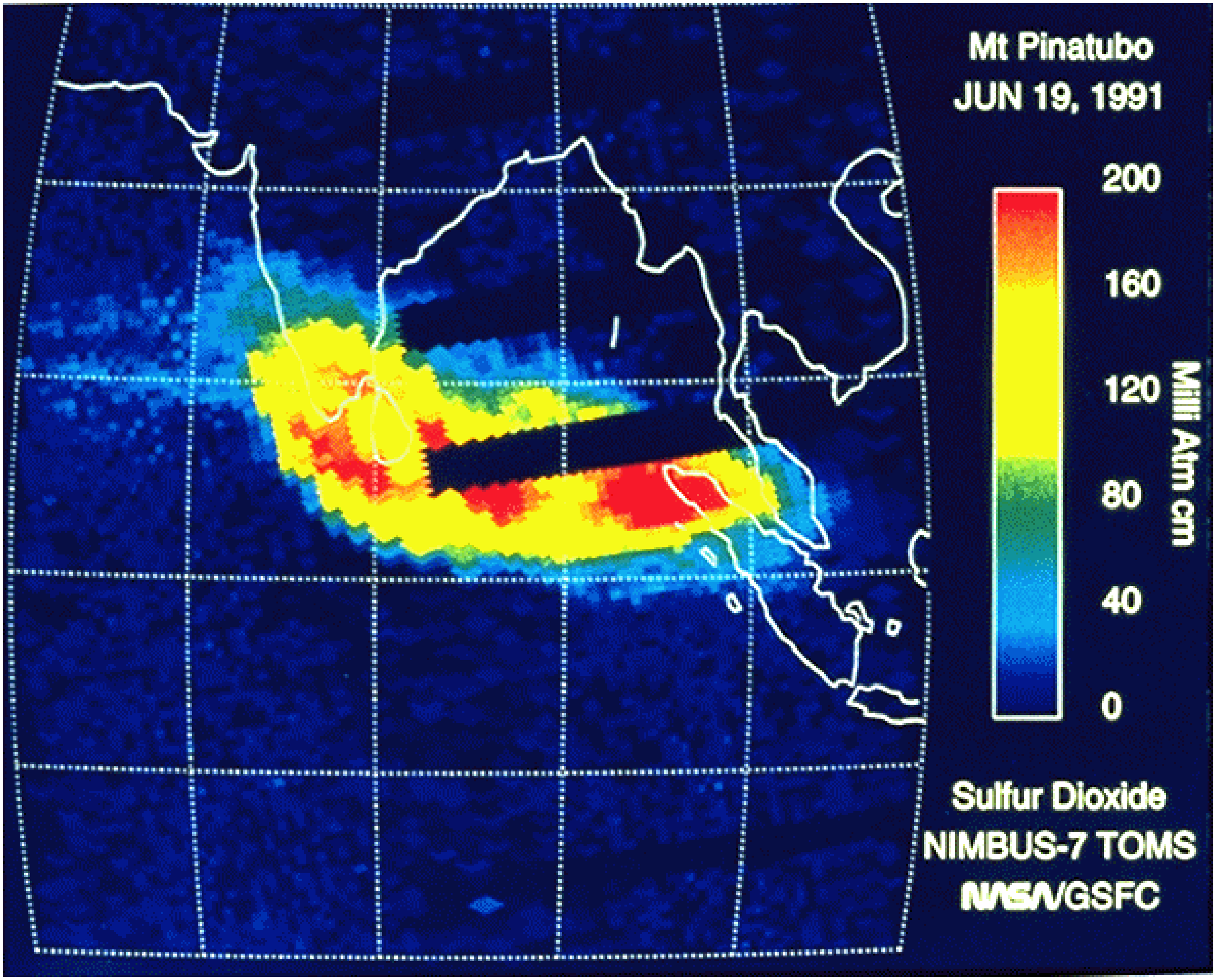

Mt Pinatubo
JUN 17, 1991
500
400
300
200
100
0
Milli Atm cm
Sulfur Dioxide
NIMBUS-7 TOMS
NASA/GSFC

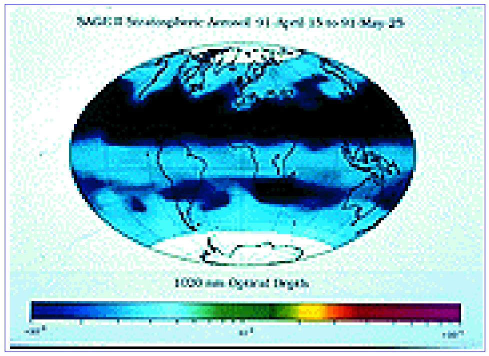

Mt Pinatubo
JUN 18, 1991
400
320
240
160
80
0
Milli Atm cm
Sulfur Dioxide
NIMBUS-7 TOMS
NASA/GSFC


Mt Pinatubo
JUN 19, 1991
200
160
120
80
40
0
Milli Atm cm
Sulfur Dioxide
NIMBUS-7 TOMS
NASA/GSFC

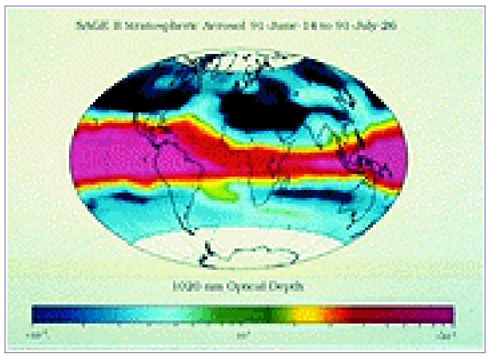
The Earth Observing System Educators' Visual Materials

ID: 7-02 a, b, c

Mount Pinatubo Stratospheric Aerosol (SAGE II)



(7-02 a)



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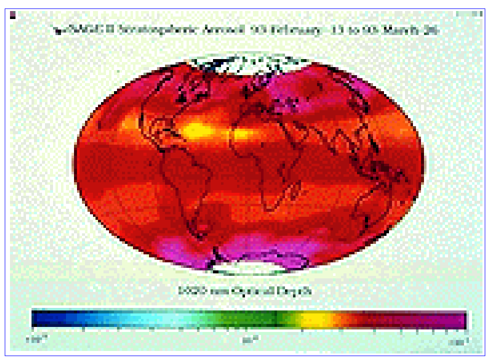

(7-02 c)

Refer to ID: 6-01 for introductory material.

The Stratospheric Aerosol and Gas Experiment II (SAGE II) was launched on the Earth Radiation Budget Satellite (ERBS) in 1984. SAGE II measures gas and aerosol extinction profiles at the Earth's limb during each solar occultation (sunrise or sunset) experienced by ERBS. Each day, 15 sunrise and 15 sunset profiles are measured with equal spacing in longitude. Because the ERBS orbit has an inclination angle of 57 degree (i.e., it is non sun-synchronous), the sampling latitude progresses northward and southward as the orbital nodes move westward with respect to the Earth-Sun line, acquiring global coverage (except for the polar regions) in about 40 days. The stratospheric optical depth, D, for a wavelength of 1020 nm, can be determined from the measured extinction profiles. Knowing D, the vertical transmittance of the solar radiation through the atmosphere can be calculated (the larger the value of D, the smaller the transmittance). In general, part of the solar radiation that is not transmitted is absorbed by the atmospheric gases and aerosols, and part is scattered, with some of the energy being scattered backward and lost to space. With less solar radiation reaching the Earth's surface, the climate cools.

Because of its high sensitivity to aerosols, its 1-km vertical resolution, and its inherent self-calibration, the SAGE II instrument provided a valuable database useful for long-term studies of aerosols produced by the eruption of Mount Pinatubo in the Philippines in mid-June 1991. The aerosol measured included crustal material as well as the sulfuric acid/water aerosol produced by the sulfur dioxide (SO_2) emitted by Pinatubo. Figures 7-02a, b, and c show the global evolution and dispersion of the Pinatubo aerosol over nearly a two-year period. The values of D are color-coded, ranging from $<10^{-3}$ (dark blue), through green, yellow, and orange, to $>10^{-1}$ (red). Figure 7-02a shows D over a 40-day period before Mount Pinatubo erupted. The value of D everywhere is low, approximately 10^{-3}. Figure 7-02b shows D over a 40-day period following the eruption of Mount Pinatubo. During this period the aerosol cloud completely encircled the globe in a narrow zone, with maximum values of D near 10^{-1}, about two orders of magnitude larger than D before the eruption. Figure 7-02c shows the distribution of D 20 months after the eruption. Here the aerosol cloud has dispersed over the globe, with values of D between 10-2 and 10-1 everywhere.

The Mount Pinatubo eruption had major impacts on the Earth system. The aerosols are believed to have contributed to reduced ozone concentrations over the polar region of the Southern Hemisphere. Total ozone column amounts for 1992 during the springtime in the antarctic stratosphere were the lowest ever observed (see Figure 6-01). Also, a global cooling was observed in 1992 making it the coolest year since 1986 (see Figure 3-01a). This cooling has been attributed in large part to the shading effects of the aerosols from Mount Pinatubo. Historically, it is interesting to note the behavior of the global surface air temperature following the massive volcanic eruption of Krakatau in 1883. The following year, 1884, was the coolest year ever recorded during the period 1880-present (see Figure 3-01a).

SAGE III, an advanced version of the SAGE II instrument, is scheduled to be launched as part of the MTPE Program.

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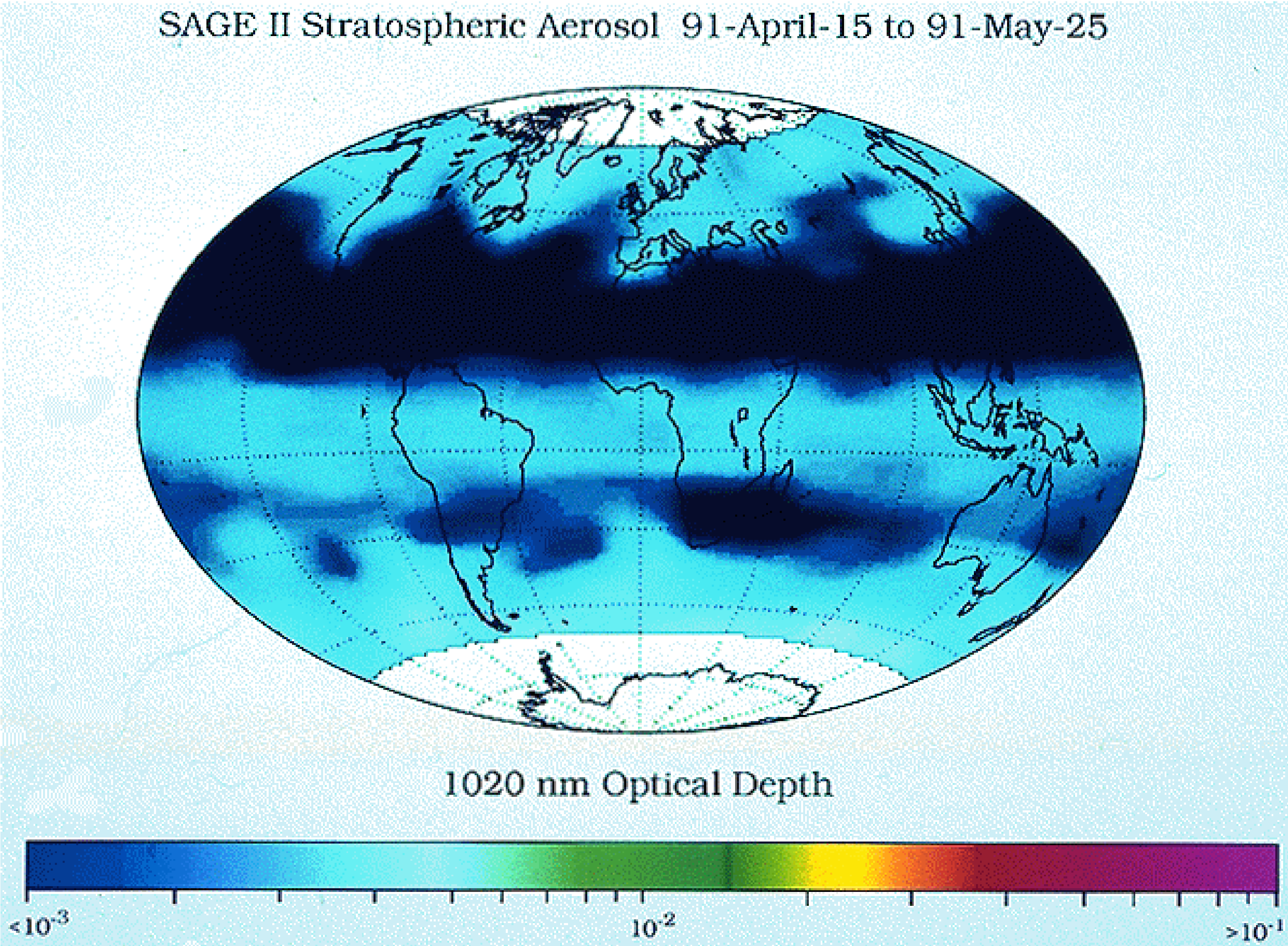
SAGE II Stratospheric Aerosol 91-April-15 to 91-May-25
1020 nm Optical Depth
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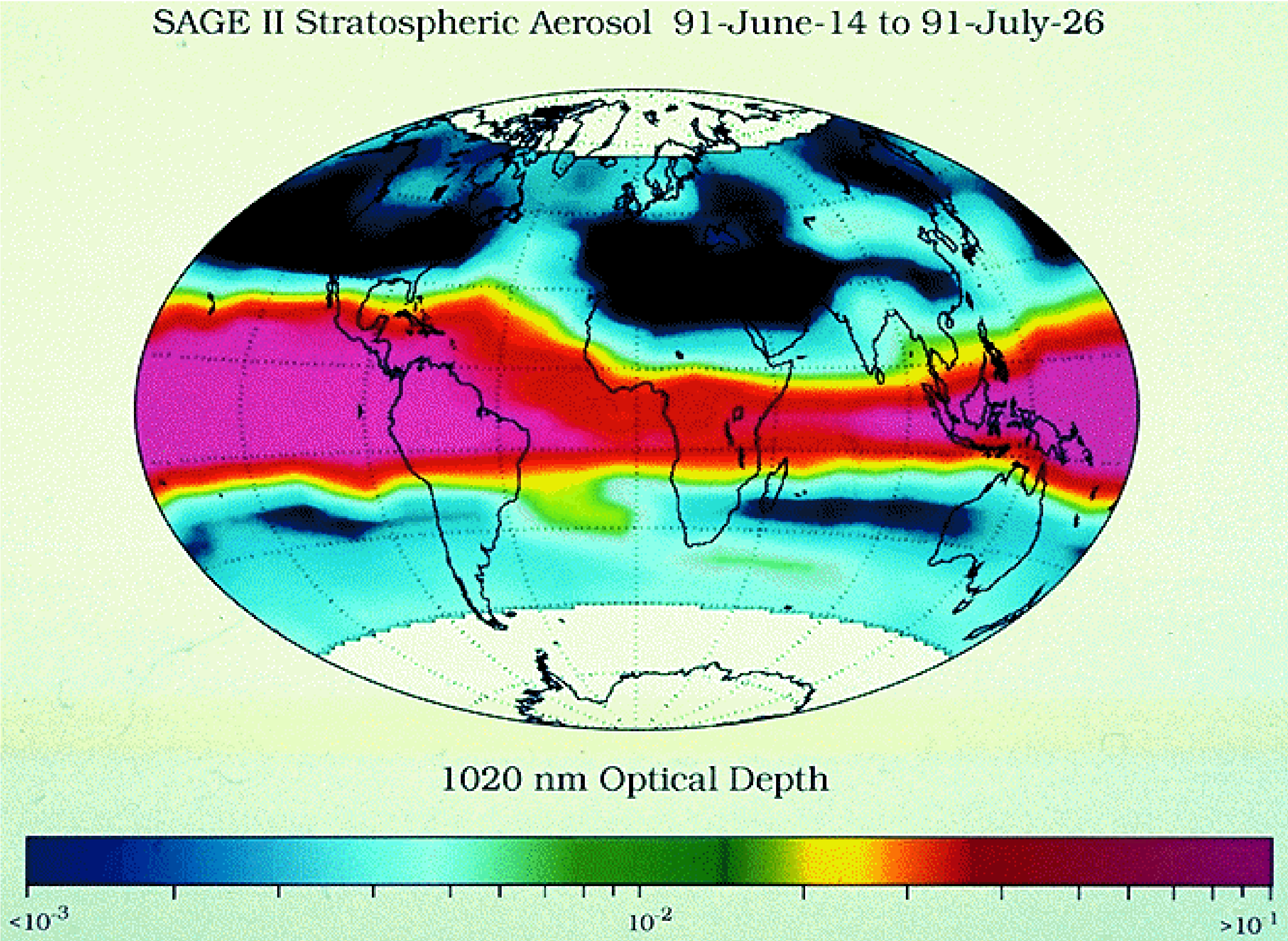
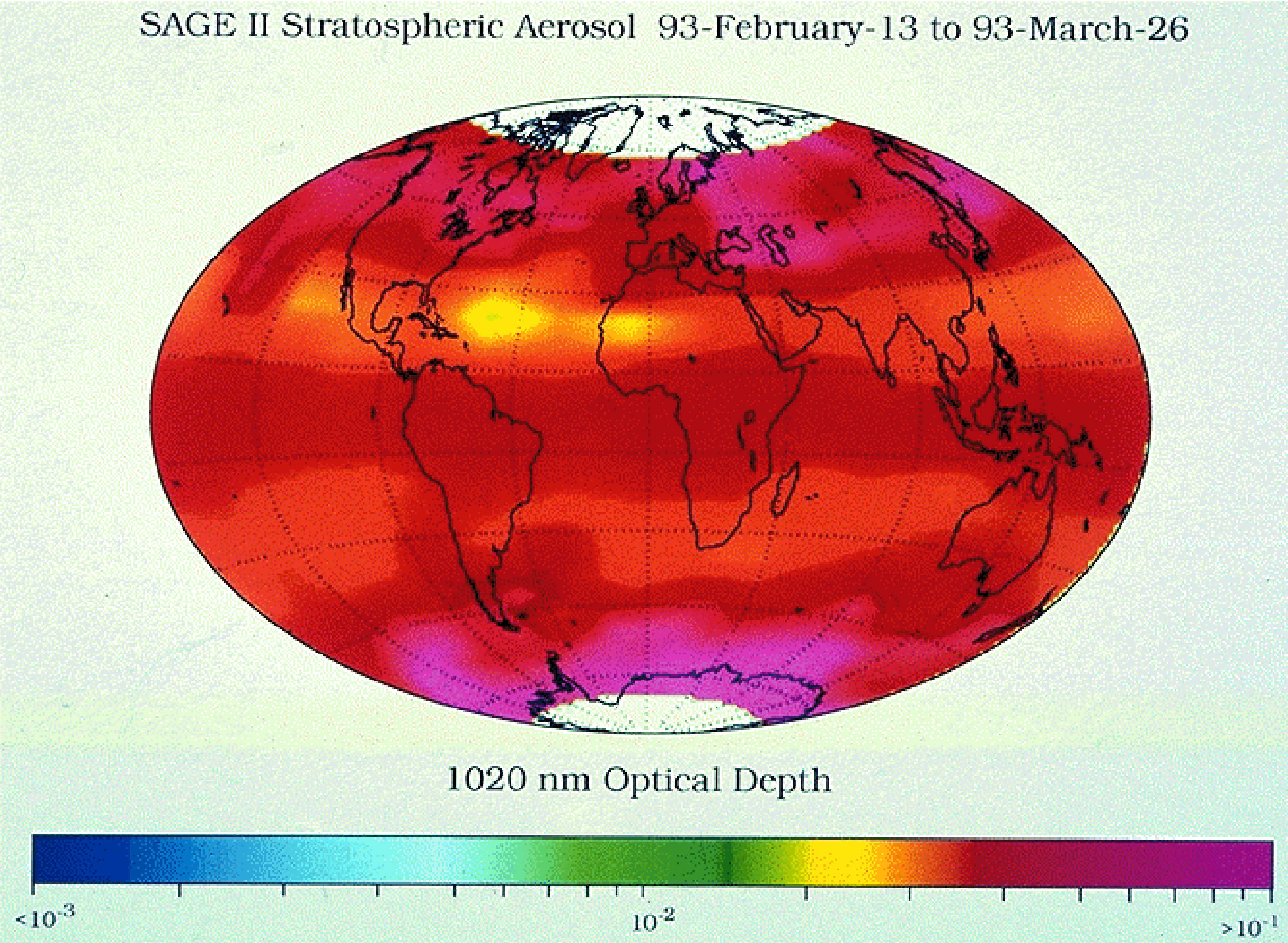
10-2
>10-1


SAGE II Stratospheric Aerosol 91-June-14 to 91-July-26
1020 nm Optical Depth
<10^-3
10^-2
>10^-1


SAGE II Stratospheric Aerosol 93-February-13 to 93-March-26
1020 nm Optical Depth
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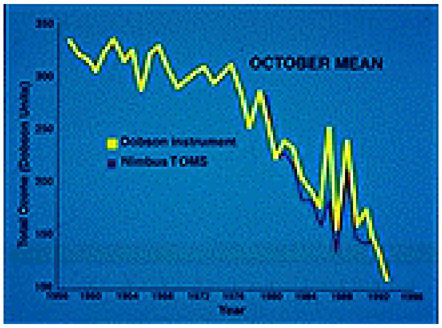
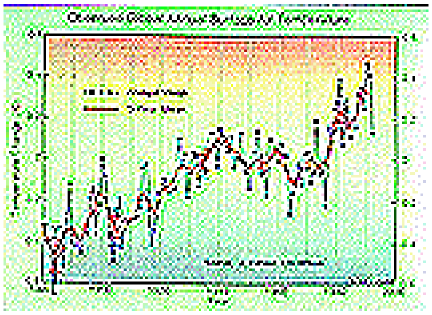
10-2
>10-1

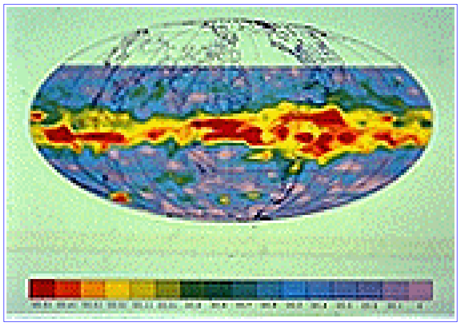

OCTOBER MEAN
Dobson instrument
Nimbus TOMS
Year



The Earth Observing System Educators' Visual Materials

ID: 7-03

Mount Pinatubo Stratospheric Aerosol (SAGE II)



Mount Pinatubo Sulfur Dioxide (MLS)

Refer to ID: for introductory material.

Mount Pinatubo, after being dormant for more than 600 years, erupted several times in June 1991 with the major event occurring on June 15, spewing approximately 20 million tons of sulfur dioxide (SO_2) into the atmosphere. By mid-July the SO_2 cloud had traveled around the entire globe (see Figure 7-01a, b, c and 7-02b). On September 21 worldwide levels of SO_2 were measured by the Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite (UARS) and are depicted in this figure. The color scale relates to SO_2 amounts in parts per billion (ppb), ranging from <1.0 (violet), through blue, green, yellow, and orange, to >10.0 (red). The SO_2 gas reacts with water in the stratosphere to form sulfuric acid aerosol particles. These particles increase the amount of sunlight reflected back to space, thus having a cooling effect on the Earth's climate. The relative cooling caused by the Mount Pinatubo eruption helped to make 1992 the coolest year since 1986 (see Figure 3-01a). Also, the resultant aerosols from the Mount Pinatubo eruption are believed to have contributed to reduced ozone concentrations over the polar region of the Southern Hemisphere (see Figure 7-04).

The MLS instrument is scheduled to be launched on the EOS-Chemistry satellite series beginning in 2002, and one of its applications will be the investigation of worldwide levels of SO_2.

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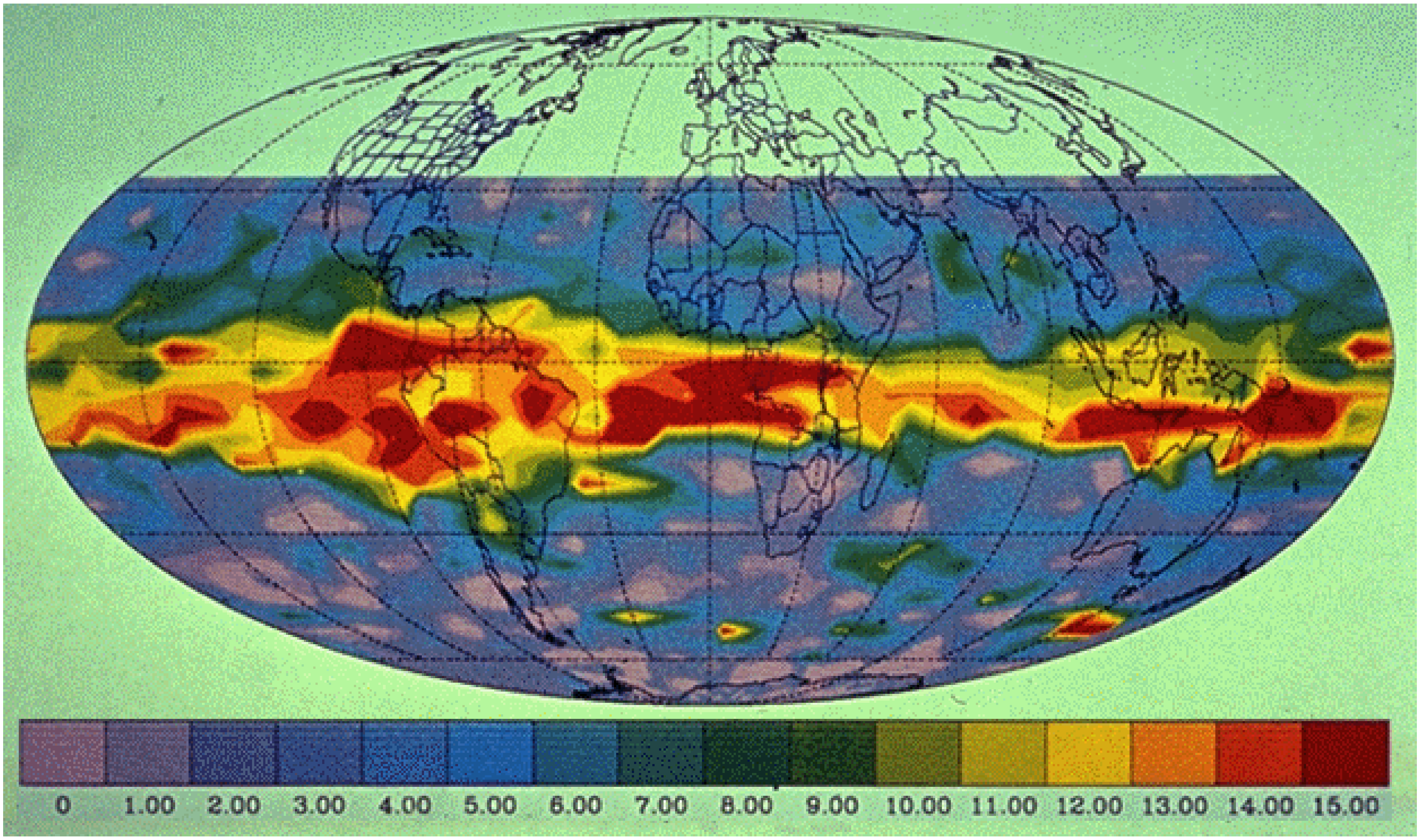
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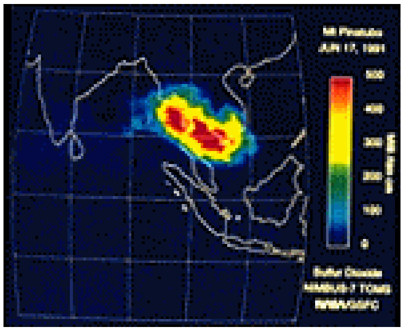

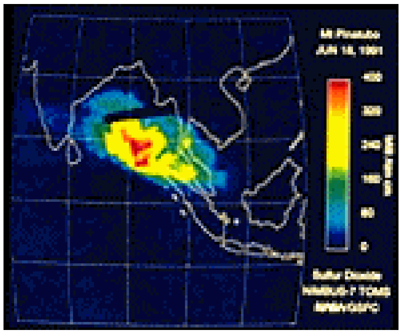

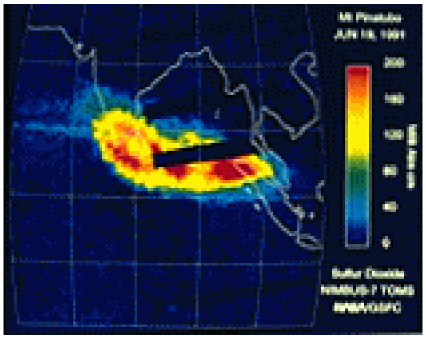
Mt Pinatubo
200
160
120
80
40
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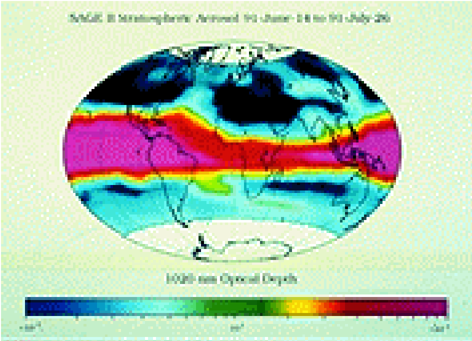
Sulfur Dioxide
NIMBUS-7 TOMS
NASA/GSFC


SAGE II Stratospheric Aerosol 91-June-14 to 91-July-26
1020 nm Optical Depth

NASA Fact Sheets

The Earth Science Enterprise Series

The Earth Science Enterprise Series and the Earth Observing System Terra Series of NASA Fact Sheets are produced in an effort to educate the general public on the major issues and natural phenomena that scientists will be studying using data provided by the Earth Observing System. With this data, we hope to gain a greater understanding of how the Earth works as a system.

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Changing Global Cloudiness (June 1999) (FS-1999-06-023-GSFC)

Changing Global Land Surface (June 1999) (FS-1999-06-024-GSFC)

Earth's Energy Balance (June 1999) (FS-1999-06-025-GSFC)

The Roles of the Ocean in Climate Change (June 1999) (FS-1999-06-026-GSFC)

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Tropical Deforestation (November 1998) (FS-1998-11-120-GSFC)

Volcanoes and Global Climate Change (April 1998) (NF-220)

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Looking at Earth From Space - Glossary

Educational Reference for Teachers--Grades 7-12

Introduction

NASA's Office of Mission to Planet Earth is responsible for mounting a global-scale examination of the Earth's environment and how it is changing. Researchers will use data from satellites carrying specialized instruments to study all components of the Earth system--air, water, land, and biota--and their interactions. NASA will archive, analyze, and distribute these data through a comprehensive data and information system. These efforts will help to increase our understanding of the global environment and how human activities affect our planet.

The NASA series of publications entitled "Looking at Earth From Space" was developed to familiarize educators with global change issues and Mission to Planet Earth, and to enable teachers to enhance classroom studies with hands-on activities using satellite images. The series, available through the NASA Teacher Resource Center network, includes:

- Direct Readout from Environmental Satellites (January 1994);
- Guide to Equipment and Vendors, which reviews hardware requirements for environmental satellite ground stations and identifies sources for the equipment (January 1994);
- Glossary of Terms which includes science and technology terms relevant to Mission to Planet Earth, remote sensing, and direct readout (Summer1994);
- Teacher's Guide to Global Change, which includes background information and lessons for high school classrooms on topics related to the science issues of global climate change (Summer 1994);
- Training Manual, designed to help teachers (elementary grades through high school) use an environmental satellite Earth station and understand the atmospheric conditions displayed in the images (Fall 1994); and
- Teacher's Resource Guide to Direct Readout, which contains lesson plans for grades 4-12 (Fall 1994).

For additional information, please contact:
Dr. Gerald Soffen (gerald_soffen@email.gsfc.naca.gov)
Director UniversityPrograms,
Goddard Space Flight Center, Code 160
Greenbelt Road, Greenbelt, Maryland 20771

Click alphabetic list to go to the specific section:

Acknowledgments

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chief, Educational Prog. Branch
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39529-6000
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Teacher Resource Center

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Manager, Educational Affairs Office
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Phone: (818) 354-8151

Teacher Resource Center

NASA Teacher Resource Center
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The Spacelink computer access number is (205) 895-0028. Users need a computer, modem, communications software, and a long-distance telephone line to access Spacelink. It is also available through the Internet, a worldwide computer network connecting a large number of educational institutions and research facilities. Callers with Internet access may reach NASA Spacelink at any of the following addresses:

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xsl.msfc.nasa.gov.
192.149.89.61
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Education Satellite Videoconference Series

The Education Satellite Videoconference Series for Teacher is offered as an inservice education program for educators through the school year. The content of each program varies, but includes aeronautics or space science topics of interest to elementary and secondary teachers. NASA program managers, scientists, astronauts, and education specialists are featured presenters. The videoconference series is free to registered educational institutions. To participate, the institution must have a C-band satellite receiving system, teacher release time, and an optional long distance telephone line for interaction. Arrangements may also be made to receive the satellite signal through the local cable television system. The programs may be videotaped and copied for later use.

For more information, contact:
Videoconference Coordinator
NASA Teaching From Space Program
Oklahoma State University
300 North Cordell
Stillwater, OK 74078-0422

Click here to retrun to Introduction page.

Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

A

- absolute humidity
- absorption
- acid rain
- Acquisition of Signal (AOS)
- active system (active sensor)
- A/D
- Advanced Very High Resolution Radiometer (AVHRR)
- aerosol
- afforestation
- AI
- AIR
- air mass
- air pollution
- air pressure
- aka
- albedo
- algorithm
- alkaline
- altimeter
- altitude
- AM
- ampere (amp)
- amplitude
- amplitude modulation (AM)
- analog
- ancillary data
- anemometer

absolute humidity In a system of moist air, the ratio of the mass of water vapor present to the volume occupied by the mixture; that is, the density of the water vapor component. Absolute humidity is normally expressed in grams of water vapor in a cubic meter of air (25 g/m3).

$$\text{absolute humidity} = \frac{\text{mass of water vapor}}{\text{volume of air}}$$

absorption The process in which radiant energy is retained by a substance. A further process always results from absorption, that is, the irreversible conversion of the absorbed radiation into some other form of energy within and according to the nature of the absorbing medium. The absorbing medium itself may emit radiation, but only after an energy conversion has occurred.

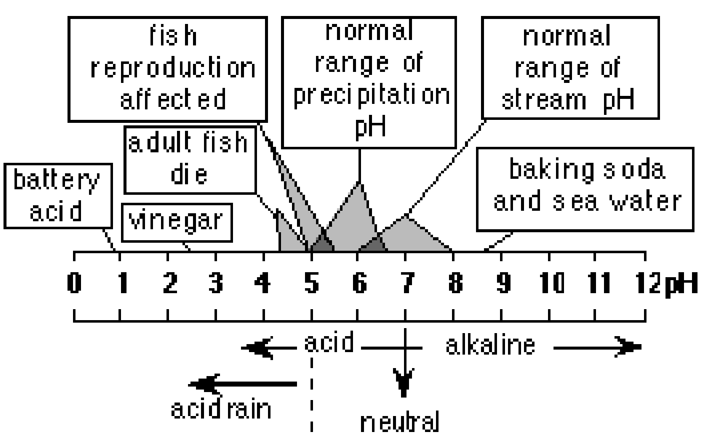
acid rain Acids form when certain atmospheric gases (primarily carbon dioxide, sulfur dioxide, and nitrogen oxides) come in contact with water in the atmosphere or on the ground and are chemically converted to acidic substances. Oxidants play a major role in several of these acid-forming processes. Carbon dioxide dissolved in rain is converted to a weak acid (carbonic acid). Other gases, primarily oxides of sulfur and nitrogen, are converted to strong acids (sulfuric and nitric acids).

Although rain is naturally slightly acidic because of carbon dioxide, natural emissions of sulfur and nitrogen oxides, and certain organic acids, human activities can make it much more acidic. Occasional pH readings of well below 2.4 (the acidity of vinegar) have been reported in industrialized areas.

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and from biological processes that occur on the land, in wetlands, and in the oceans. The effects of acidic deposits have been detected in glacial ice thousands of years old in remote parts of the globe. Principal human sources are industrial and power-generating plants and transportation vehicles. The gases may be carried hundreds of miles in the atmosphere before they are converted to acids and deposited.

Since the industrial revolution, emissions of sulfur and nitrogen oxides to the atmosphere have increased. Industrial and energy-generating facilities that burn fossil fuels, primarily coal, are the principal sources of increased sulfur oxides. These sources, plus the transportation sector, are the major originators of increased nitrogen oxides.

The problem of acid rain not only has increased with population and industrial growth, it has become more widespread. The use of tall smokestacks to reduce local pollution has contributed to the spread of acid rain by releasing gases into regional atmospheric circulation. The same remote glaciers that provide evidence of natural variability in acidic deposition show, in their more recently formed layers, the increased deposition caused by human activity during the past half century.



Acquisition of Signal (AOS) The time you begin receiving a signal from a spacecraft. For polar-orbiting satellites, radio reception of the APT signal can begin only when the polar-orbiting satellite is above the horizon of a particular location. This is determined by both the satellite and its particular path during orbit across the reception range of a ground station.

active system (active sensor) A remote-sensing system that transmits its own radiation to detect an object or area for observation and receives the reflected or transmitted radiation. Radar is an example of an active system. Compare with passive system.

A/D Analog to Digital. Used to refer to the conversion of analog data to its digital equivalent.

Advanced Very High Resolution Radiometer (AVHRR) A five-channel scanning instrument that quantitatively measures electromagnetic radiation, flown on NOAA environmental satellites. AVHRR remotely determines cloud cover and surface temperature. Visible and infrared detectors observe vegetation, clouds, lakes, shorelines, snow, and ice. TIROS Automatic Picture Transmissions (APT) are derived from this instrument. See TIROS.

aerosol Particles of liquid or solid dispersed as a suspension in gas.

afforestation The act or process of establishing a forest, especially on land not previously forested.

AI See artificial intelligence.

AIR Airborne Imaging Radar.

air mass Large body of air, often hundreds or thousands of miles across, containing air of a similar temperature and humidity. Sometimes the differences between air masses are hardly noticeable, but if colliding air masses have very different temperatures and humidity values, storms can erupt. See front.

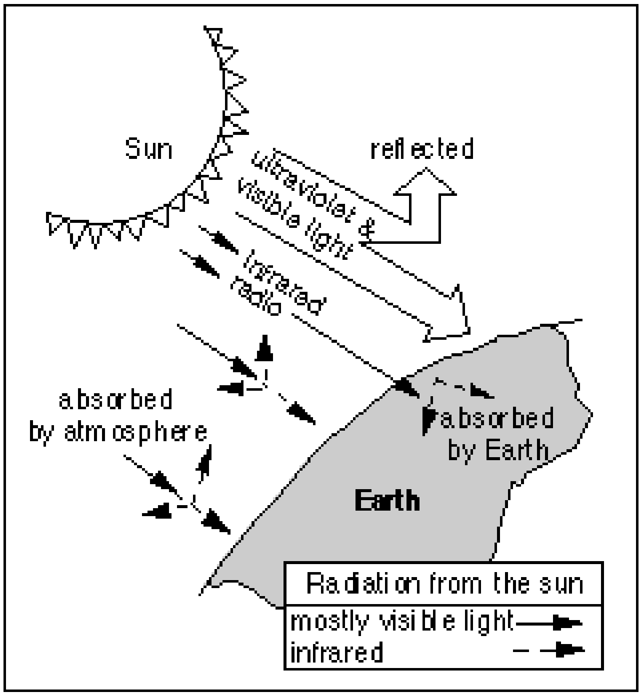
air pollution The existence in the air of substances in concentrations that are determined unacceptable. Contaminants in the air we breathe come mainly from manufacturing industries, electric power plants, automobiles, buses, and trucks.

Primary Air Pollutants
sulfur dioxide
carbon monoxide
nitrogen dioxide
ground-level ozone
lead
carbon particles

air pressure The weight of the atmosphere over a particular point, also called barometric pressure. Average air exerts approximately 14.7 pounds (6.8 kg) of force on every square inch (or 101,325 newtons on every square meter) at sea level.

aka Also known as.

albedo The ratio of the outgoing solar radiation reflected by an object to the incoming solar radiation incident upon it.



algorithm A mathematical relation between an observed quantity and a variable used in a step-by-step mathematical process to calculate a quantity.

In the context of remote sensing, algorithms generally specify how to determine higher-level data products from lower-level source data. For example, algorithms prescribe how atmospheric temperature and moisture profiles are determined from a set of radiation observations originally sensed by satellite sounding instruments.

alkaline Substance capable of neutralizing acid, with a pH greater than 7.0. See pH.

altimeter An active instrument (see active system) used to measure the altitude of an object above a fixed level. For example, a laser altimeter can measure height from a spacecraft to an ice-sheet. That measurement, coupled with radial orbit knowledge, will enable determination of the topography.

altitude Height above the Earth's surface.

AM See amplitude modulation.

ampere (amp) Standard unit to measure the strength of an electric current. One amp is the amount of current produced by an electromotive force of one volt acting through the resistance of one ohm. The ampere is 10-1 of the theoretical electromagnetic unit of current. Named for the French physicist Andre Marie Ampere. See ohm.

amplitude The magnitude of the displacement of a wave from a mean value. For a simple harmonic wave, it is the maximum displacement from the mean. For more complex wave motion, amplitude is usually taken as one-half of the mean distance (or difference) between maxima and minima.

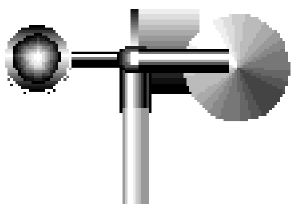
amplitude modulation (AM) One of three ways to modify a sine wave signal in order to make it "carry" information.

The strength (amplitude) of a signal varies (modulates) to correspond to the transmitted information. As applied to APT, an audible tone of 2400 Hz is amplitude modulated, with the maximum signal corresponding to light areas of a photograph, the minimum levels black, and the intermediate strengths various shades of gray. See grayscale.

analog Transmission of a continuously variable signal as opposed to a discretely variable signal. Compare with digital. A system of transmitting and receiving information in which one value (i.e., voltage, current, resistance, or, in the APT system, the volume level of the video tone) can be compared directly to the information (in the APT system, the white, black, and gray values) in the image.

ancillary data Data other than instrument data required to perform an instrument's data processing. Ancillary data includes such information as orbit and/or attitude data, time information, spacecraft engineering data, and calibration information.

anemometer Instrument used to measure wind speed, usually measured either from the rotation of wind-driven cups or from wind pressure through a tube pointed into the wind.



anomaly

1. The deviation of (usually) temperature or precipitation in a given region over a specified period from the normal value for the same region.
2. The angular distance of an Earth satellite (or planet) from its perigee (or perihelion) as seen from the center of the Earth (sun). See Keplerian elements for examples of use.

antenna A wire or set of wires used to send and receive electromagnetic waves. Two primary features must be considered when selecting antennas: beamwidth, or the "width" of the antenna pattern (wide beamwidth suggests the ability to receive signals from a number of different directions), and gain, or the increase in signal level. Generally beamwidth or gain can be increased only at the expense of the other. Gain can be increased by multiplying the number of antenna elements, although this adds "directionality" that reduces beamwidth.

Important antenna considerations include the following:

1. The physical size of antenna components is determined by the frequency of the transmissions it will receive--the higher the frequency, the shorter the elements. At high frequencies, use of a satellite dish will compensate for the reduced amount of energy intercepted by shortened components.
2. The antenna design should fit the type of radio frequency (RF) signal polarization it will receive. The orientation of radio waves in space is a function of the orientation of the elements of the transmitting antenna. A circularly polarized wave rotates as it propagates through space. Antennas can be designed for either right or left-handed circular polarization. Earth-based communication antennas are either vertical or horizontal in polarization, and not suited for space communication. Police and cellular phone transmissions use vertical polarization because a simple vertical whip

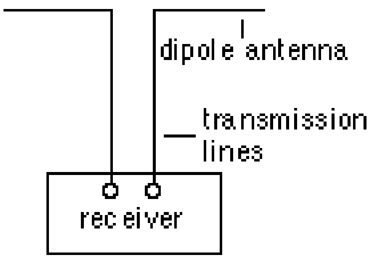
antenna is the easiest sort of omnidirectional antenna to mount on a vehicle.

3. The antenna needs to produce sufficient signal gain to produce noise-free reception.
4. The antenna should be clear of conductive objects such as power lines, phone wires, etc., so height about the ground becomes important.

Basic antenna components are:

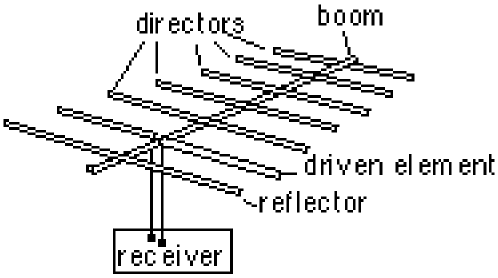
1. Driven element--the parts connected to and receiving power from the receiver/transmitter;
2. Parasitic elements--the parts dependent upon resonance rather than connection to a power source;
   - A director or parasitic element that reinforces radiation on a line pointing to it from the driven element;
   - A reflector or parasitic element that reinforces radiation on a line pointing from it to the driven element.

A fundamental form of antenna is a single wire whose length approximately equals half the transmitting wavelength. Known as a dipole antenna, it is the unit from which many more complex forms of antennas are constructed.



dipole antenna

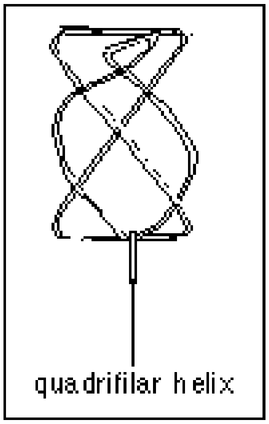
One of the most common forms of VHF antenna is the Yagi/beam, named for the Japanese scientist who first described the principles of combining a basic dipole (driven element) and parasitic elements. A common TV antenna is an example of this type. A Yagi/beam antenna is directional and therefore includes a rotator to aim (direct) the antenna. See yagi.

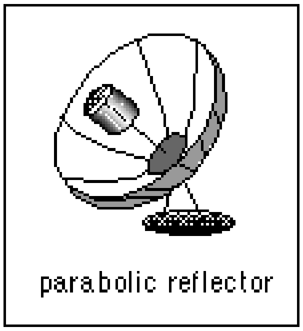


Yagi/beam antenna

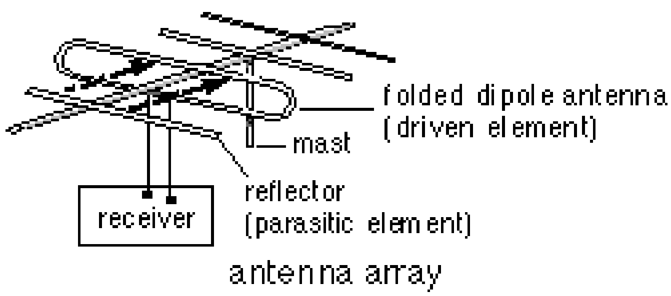
An omnidirectional antenna has a wide beamwidth and consequently does not require "tracking" (aiming the antenna toward the signal source). An example of an omnidirectional antenna is the turnstile antenna, a variation of the standard dipole antenna well suited for space communications. The quadrifilar helix antenna is omnidirectional and an inherently excellent antenna for ground station use. Quadrifilars are also used on NOAA's polar-orbiting environmental satellites.

The parabolic reflector or satellite dish antenna collects RF signals on a passive dish-shaped surface. A feedhorn antenna--a simple dipole antenna mounted in a resonant tube structure (cylinder with one open end)--transfers the RF energy to a transmission line. The bigger the dish, the greater the amount of RF energy intercepted, and therefore the greater the gain from the signal.





antenna array An ordered assembly of elementary antennae spaced apart and fed in such a manner that the resulting radiation is concentrated in one or more directions.



antenna beam The focused pattern of electromagnetic radiation that is either received or transmitted by an antenna.

anticyclone A high pressure area where winds blow clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. See cyclone, wind.

AOS See Acquisition of Signal.

apogee (aka apoapsis or apifocus) On an elliptical orbit path, the point at which a satellite is farthest from the Earth.

APT See Automatic Picture Transmission.

aquifer Layer of water-bearing permeable rock, sand, or gravel capable of providing significant amounts of water.

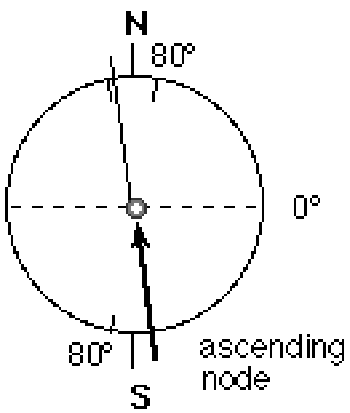
ARGOS French random-access Doppler data collection system. Used on NOAA's Polar-Orbiting Environmental Satellites (POES), ARGOS receives platform and buoy transmissions on 401.65 MHz. This data collection system now monitors more than 4,000 platforms worldwide, outputs data via VHF link, and stores them on tape for relay to a central processing facility.

argument of perigee (aka ARGP or w) One of the six Keplerian elements, it gives the rotation of the satellite on the orbit. The argument (argument meaning angle) of perigee--perigee is the point on an orbital path when the satellite is closest to the Earth--is the angle (measured from the center of the Earth) from the ascending node to perigee. Example: When ARGP = 0 degree, the perigee occurs at the same place as the ascending node. That means that the satellite would be closest to Earth just as it rises up over the equator. When ARGP = 180 degrees, apogee would occur at the same place as the descending node. This means that the satellite would be farthest from Earth just as it rises over the equator. See Keplerian elements for diagram.

Arctic circle The parallel of latitude that is approximately 66.5 degrees north of the equator and that circumscribes the northern frigid zone.

artificial intelligence Neural networks. The branch of computer science that attempts to program computers to respond as if they were thinking--capable of reasoning, adapting to new situations, and learning new skills. Examples of artificial intelligence programs include those that can locate minerals underground and understand human speech.

ascending node The point in an orbit (longitude) at which a satellite crosses the equatorial plane from south to north.

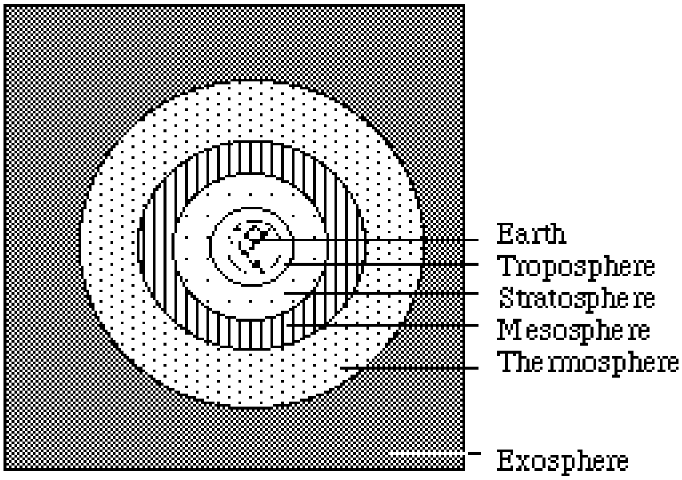


aspect ratio The ratio of image width to image height. Weather Facsimile (WEFAX) images have a 1:1 aspect ratio (square); a conventional TV aspect ratio is 4:3 (rectangle).

Astronomical Unit (AU) The distance from the Earth to the sun. On average, the sun is 149,599,000 kilometers from Earth.

ATLAS (Atmospheric Laboratory for Applications and Science) mission The focus of ATLAS is to study the chemistry of the Earth's upper atmosphere (mainly the stratosphere/mesosphere) and the solar radiation incident on the Earth system (both total solar irradiance and spectrally resolved radiance, especially ultraviolet). Science operations onboard ATLAS 1 (March 1992) and ATLAS 2 (March-April, 1993) began a comprehensive and systematic collection of data that will help establish benchmarks for atmospheric conditions and the sun's stability.

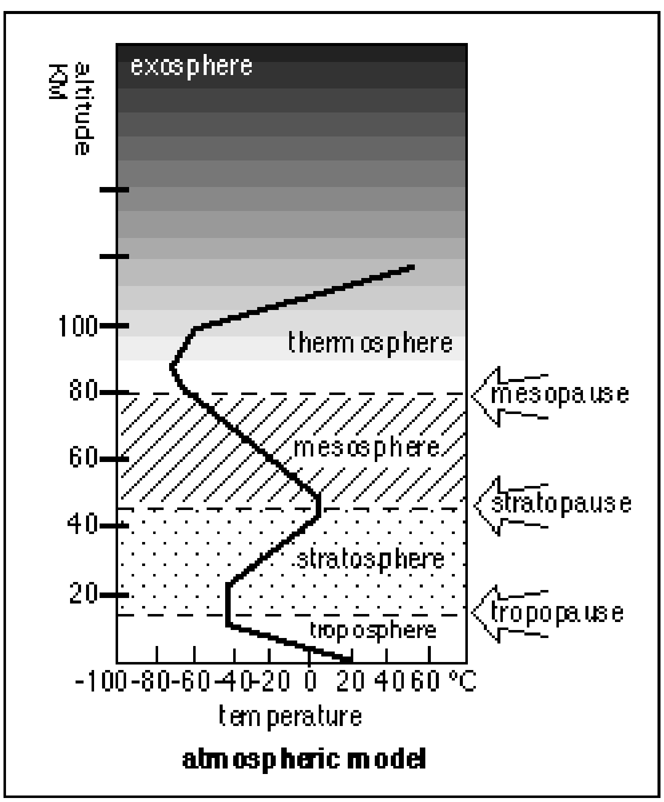
atmosphere The air surrounding the Earth, described as a series of shells or layers of different characteristics. The atmosphere, composed mainly of nitrogen and oxygen with traces of carbon dioxide, water vapor, and other gases, acts as a buffer between Earth and the sun. The layers, troposphere, stratosphere, mesosphere, thermosphere, and the exosphere, vary around the globe and in response to seasonal changes.



Troposphere stems from the Greek word tropos, which means turning or mixing. The troposphere is the lowest layer of the Earth's atmosphere, extending to a height of 8-15 km, depending on latitude. This region, constantly in motion, is the most dense layer of the atmosphere and the region that essentially contains all of Earth's weather. Molecules of nitrogen and oxygen compose the bulk of the troposphere.

The tropopause marks the limit of the troposphere and the beginning of the stratosphere. The temperature above the tropopause increases slowly with height up to about 50 km.

The stratosphere and stratopause stretch above the troposphere to a height of 50 km. It is a region of intense interactions among radiative, dynamical, and chemical processes, in which horizontal mixing of gaseous components proceeds much more rapidly that vertical mixing. The stratosphere is warmer than the upper troposphere, primarily because of a stratospheric ozone layer that absorbs solar ultraviolet energy.



The mesosphere, 50 to 80 km above the Earth, has diminished ozone concentration and radiative cooling becomes relatively more important. The temperature begins to decline again (as it does in the troposphere) with altitude. Temperatures in the upper mesosphere fall to -70 degrees to -140 degrees Celsius, depending upon latitude and season. Millions of meteors burn up daily in the mesosphere as a result of collisions with some of the billions of gas particles contained in that layer. The collisions create enough heat to burn the falling objects long before they reach the ground.

The stratosphere and mesosphere are referred to as the middle atmosphere. The mesopause, at an altitude of about 80 km, separates the mesosphere from the thermosphere--the outermost layer of the Earth's atmosphere.

The thermosphere, from the Greek thermo for heat, begins about 80 km above the Earth. At these high altitudes, the residual atmospheric gases sort into strata according to molecular mass. Thermospheric temperatures increase with altitude due to absorption of highly energetic solar radiation by the small amount of residual oxygen still present. Temperatures can rise to 2,000 degrees C. Radiation causes the scattered air particles in this layer to become charged electrically, enabling radio waves to bounce off and be received beyond the horizon. At the exosphere, beginning at 500 to 1,000 km above the Earth's surface, the atmosphere blends into space. The few particles of gas here can reach 4,500 degrees F (2,500 degrees C) during the day.

Atmospheric Infrared Sounder Advanced sounding instrument selected to fly on the EOS-PM1 mission (intermediate-sized, sun-synchronous, morning satellite) in the year 2000. It will retrieve vertical temperature and moisture profiles in the troposphere and stratosphere. Designed to achieve temperature retrieval accuracy of 1 degree C with a 1 km vertical resolution, it will fly with two operational microwave sounders. The three instruments will constitute an advanced operational sounding system, relative to the TIROS Operational Vertical Sounder (TOVS) currently flying on NOAA Polar-orbiting satellites. See Earth observing System, TIROS-N/NOAA Satellites.

Atmospheric pressure The amount of force exerted over a surface area, caused by the weight of air molecules above it. As elevation increases, fewer air molecules are present. Therefore, atmospheric pressure always decreases with increasing height. A column of air, 1 square inch in cross section, measured from sea level to the top of the atmosphere would weigh approximately 14.7 lb/in2. The standard value for atmospheric pressure at sea level is:

29.92 inches or 760 mm of mercury
1013.25 millibars (mb) or 101,325 pascals (pa).

Atmospheric Radiation Measurements Program (ARM) U.S. Department of energy program for the continual, ground-based measurements of atmospheric and meteorological parameters over approximately a ten-year period. The program will study radiative forcing and feedbacks, particularly the role of clouds. The general program goal is to improve the performance of climate models, particularly general circulation models of the atmosphere.

atmospheric response variables Variables that reflect the response of the atmosphere to external forcing (e.g., temperature, pressure, circulation, and precipitation).

atmospheric windows The range of wavelengths at which water vapor, carbon dioxide, or other atmospheric gases only slightly absorb radiation. Atmospheric windows allow the Earth's radiation to escape into space unless clouds absorb the radiation. See greenhouse effect.

atoll A coral island consisting of a ring of coral surrounding a central lagoon. Atolls are common in the Indian and Pacific Oceans.

attenuation The decrease in the magnitude of current, voltage, or power of a signal in transmission between points. Attenuation may be expressed in decibels, and can be caused by interferences such as rain, clouds, or radio frequency signals.

audio frequencies Frequencies that the human ear can hear (usually 30 to 20,000 cycles per second).

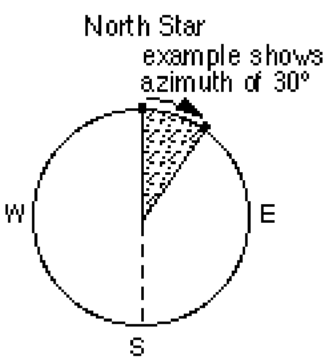
auroras See solar wind.

Automatic Picture Transmission (APT) System developed to make real-time reception of satellite images possible whenever an APT-equipped satellite passes within range of an environmental satellite ground station. Transmission (analog video format) consists of an amplitude-modulated audible tone that can be displayed as an image on a computer monitor when received by an appropriate ground station.

APT images are transmitted by polar-orbiting satellites such as the TIROS-N/NOAA satellites, Russias METEOR, and the Chinese Feng Yun, which orbit 500-900 miles above the Earth, and offer both visible and infrared iamges. An APT image has thousands of squares called picture elements of pixels. Each pixel represents a four-km square.

AVHRR See Advanced Very High Resolution Radiometer.

azimuth The direction, in degrees referenced to true north, that an antenna must be pointed to receive a satellite signal (compass direction). The angular distance is measured in a clockwise direction.



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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

B

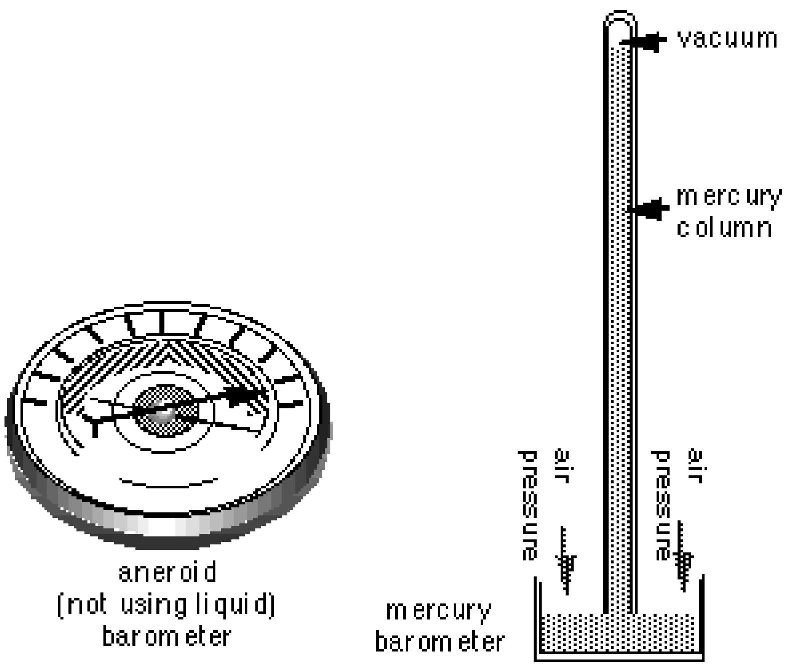
- band
- bandwidth
- barometer
- base
- BASIC
- baud
- bay
- beamwidth
- bearing
- Beginners
- binary
- bioassay
- biodegradation
- biogeochemical cycles
- biomass
- biome
- biosphere
- biota
- bit
- bit rate
- blizzard
- boundaries
- BTU
- bus
- byte

band

- In radio, a continuous sequence of broad-casting frequencies within given limits.
- In radiometry, a relatively narrow region of the electromagnetic spectrum to which a remote sensor responds; a multispectral sensor makes measurements in a number of spectral bands.
- In spectroscopy, spectral regions where atmospheric gases absorb (and emit) radiation, e.g., the 15 µm carbon dioxide absorption band, the 6.3 µm water vapor absorption band, and the 9.6 µm ozone absorption band.

bandwidth The total range of frequency required to pass a specific modulated signal without distortion or loss of data. The ideal bandwidth allows the signal to pass under conditions of maximum AM or FM adjustment. (Too narrow a bandwidth will result in loss of data during modulation peaks. Too wide a bandwidth will pass excessive noise along with the signal.) In FM, radio frequency signal bandwidth is determined by the frequency deviation of the signal.

barometer An instrument used to measure atmospheric pressure. A standard mercury barometer has a glass column about 30 inches long, closed at one end, with a mercury-filled reservoir. Mercury in the tube adjusts until the weight of the mercury column balances the atmospheric force exerted on the reservoir. High atmospheric pressure forces the mercury higher in the column. Low pressure allows the mercury to drop to a lower level in the column. An aneroid barometer uses a small, flexible metal box called an aneroid cell. The box is tightly sealed after some of the air is removed, so that small changes in external air pressure cause the cell to expand or contract.



base A substance that forms a salt when it reacts with acid. A base is a substance that removes hydrogen ions (protons) from an acid and combines with them in a chemical reaction.

BASIC See Beginners All-purpose Symbolic Instruction Code

baud Unit of signaling speed. The speed in bauds is the number of discrete conditions or signal events per second. If each signal event represents only one bit condition, baud is the same as bits per second.

bay A wide area of water extending into land from a sea or lake.

beamwidth The measure of the "width" of an antenna pattern, measured in degrees of arc. Generally an antenna with low gain has a wide pattern, receiving signals well from a number of different directions. See antenna.

bearing The combination of antenna azimuth and elevation required to point (aim) an antenna at a spacecraft. The bearing for geostationary (i.e., GOES) satellites is constant. The bearing for polar-orbiting satellites varies continuously.

Beginners All-purpose Symbolic Instruction Code (BASIC) A most popular and widespread "high level" language for microcomputers. BASIC uses a sequence of English-like commands and statements.

binary A numbering system that uses only 1 and 0 (e.g., 1 is one, 10 is two, 11 is three). In digital integrated circuits, a 0 is indicated by a logic low and a 1 by a logic high.

bioassay A measurement of the effects of a substance on living organisms.

biodegradation Decomposition of material by microorganisms.

biogeochemical cycles Movements through the Earth system of key chemical constituents essential to life, such as carbon, nitrogen, oxygen, and phosphorus.

biomass The amount of living material in unit area or volume, usually expressed as mass or weight.

biome Well-defined terrestrial environment (e.g., desert, tundra, or tropical forest). The complex of living organisms found in an ecological region.

biosphere Part of the Earth system in which life can exist, between the outer portion of the geosphere and the inner portion of the atmosphere.

biota The plant and animal life of a region or area.

bit A contraction of "binary digit." The basic element of a two-element (binary) computer language.

bit rate The speed at which bits are transmitted, usually expressed in bits per second. See baud.

blizzard A severe weather condition characterized by low temperatures and strong winds (greater than 35 mph) bearing a great amount of snow, either falling or blowing. When these conditions persist after snow has stopped falling, it is called a ground blizzard.

boundaries Lines indicating the limits of countries, states, or other political jurisdictions, or different air masses.

British Thermal Unit (BTU) The amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit. Compare with calorie.

bus The basic frame of a satellite system that includes the propulsion and stabilization systems but not the instruments or data systems.

byte A unit of eight bits of data or memory in microcomputer systems.

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Concepts and Terms

C

calibration Act of comparing an instrument's measuring accuracy to a known standard.

calorie The amount of heat needed to raise the temperature of one gram of water at 15 degrees centigrade one degree centigrade. Compare with British Thermal Unit.

canal A man-made watercourse designed to carry goods or water.

canopy The layer formed naturally by the leaves and branches of trees and plants.

canyon A large but narrow gorge with deep sides.

cape (or point) A piece of land extending into water.

carbon cycle All parts (reservoirs) and fluxes of carbon. The cycle is usually thought of as four main reservoirs of carbon interconnected by pathways of exchange. The reservoirs are the atmosphere, terrestrial biosphere (usually includes freshwater systems), oceans, and sediments (includes fossil fuels). The annual movements of carbon, the carbon exchanges between reservoirs, occur because of various chemical, physical, geological, and biological processes. The ocean contains the largest pool of carbon near the surface of the Earth, but most of that pool is not involved with rapid exchange with the atmosphere.

carbon dioxide A minor but very important component of the atmosphere, carbon dioxide traps infrared radiation. Atmospheric CO2 has increased about 25 percent since the early 1800s, with an estimated increase of 10 percent since 1958 (burning fossil fuels is the leading cause of increased CO2, deforestation the second major cause). The increased amounts of CO2 in the atmosphere enhance the greenhouse effect, blocking heat from escaping into space and contributing to the warming of Earth's lower atmosphere.

carrier Radio frequency capable of being modulated with some type of information. See modulation.

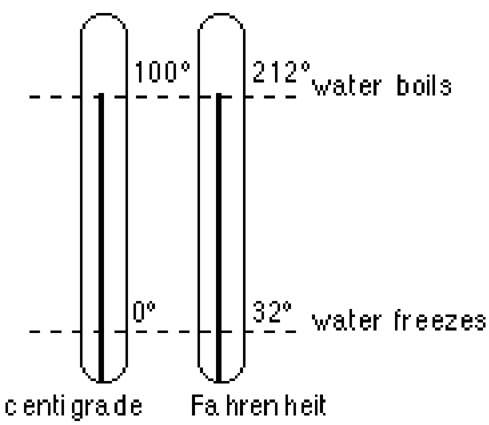
carrying capacity The steady-state density of a given species that a particular habitat can support.

catalog number A five-digit number assigned to a cataloged orbiting object. This number may be found in the NASA Satellite Situation Report and on the NASA Prediction Bulletins.

cathode ray tube (CRT) A television picture tube for image display.

CD-ROM See Compact Disk-Read Only Memory.

centigrade Temperature scale proposed by Swedish astronomer Anders Celsius in 1742. A mixture of ice and water is zero on the scale; boiling water is designated as 100 degrees. A degree is defined as one hundredth of the difference between the two reference points, resulting in the term centigrade (100th part).



To convert centigrade to Fahrenheit: multiply the centigrade temperature by 1.8 and add 32 degrees. $F = 9/5\,C + 32$ To convert Fahrenheit to centigrade: subtract 32 degrees from the Fahrenheit temperature and divide the quantity by 1.8. $C = (F - 32) / 1.8$.

central processing unit (CPU) Main part of a computer consisting of an arithmetic logic unit and a control unit. See microprocessor.

CFC See chlorofluorocarbon.

chlorofluorocarbon (CFC) A family of compounds of chlorine, fluorine, and carbon, entirely of industrial origin. CFCs include refrigerants, propellants for spray cans (this usage is banned in the U.S., although some other countries permit it) and for blowing plastic-foam insulation, styrofoam packaging, and solvents for cleaning electronic circuit boards. The compounds' lifetimes vary over a wide range, exceeding 100 years in some cases.

CFCs' ability to destroy stratospheric ozone through catalytic cycles is contributing to the depletion of ozone worldwide. Because CFCs are such stable molecules, they do not react easily with other chemicals in the lower atmosphere. One of the few forces that can break up CFC molecules is ultraviolet radiation, however the ozone layer protects the CFCs from ultraviolet radiation in the lower atmosphere. CFC molecules are then able to migrate intact into the stratosphere, where the molecules are bombarded by ultraviolet rays, causing the CFCs to break up and release their chlorine atoms. The released chlorine atoms participate in ozone destruction, with a single atom of chlorine able to destroy ozone molecules over and over again.

International attention to CFCs resulted in a meeting of diplomats from around the world in Montreal in 1987. They forged a treaty that called for drastic reductions in the production of CFCs. In 1990, diplomats met in London and voted to significantly strengthen the Montreal Protocol by calling for a complete elimination of CFCs by the year 2000.

Circadian Rhythm The cyclical changes in physiological processes and functions that are related to the 24-hour diurnal cycle.

circuit The complete path of an electric current; an assemblage of electronic elements; a means of two-way communication between two points--comprised of associated "go" and "return" channels.

circularly polarized RF Radio frequency transmissions where the wave energy is divided equally between a vertically and a horizontally polarized component.

Clarke Belt A belt 22,245 miles (35,800 kilometers) directly above the equator where a satellite orbits the Earth at the same speed the Earth is rotating. Science fiction writer and scientist Arthur C. Clarke wrote about this belt in 1945, hence the name.

climate The average weather conditions in an area determined over a period of years.

climatology Science dealing with climate and climate phenomena.

clone A person or thing very much like another, e.g., a copy of another manufacturer's computer.

cloudburst Any sudden, heavy rain shower.

clouds A visible mass of liquid water droplets suspended in the atmosphere above Earth's surface. Clouds form in areas where air rises and cools. The condensing water vapor forms small droplets of water (0.012 mm) that, when combined with billions of other droplets, form clouds. Clouds can form along warm and cold fronts, where air flows up the side of the mountain and cools as it rises higher into the atmosphere, and when warm air blows over a colder surface, such as a cool body of water.

Clouds fall into two general categories: sheet-like or layer-looking stratus clouds (stratus means layer) and cumulus clouds (cumulus means piled up). These two cloud types are divided into four more groups that describe the cloud's altitude.

High clouds form above 20,000 feet in the cold region of the troposphere, and are denoted by the prefix CIRRO or CIRRUS. At this altitude water almost always freezes so clouds are composed of ice crystals. The clouds tend to be wispy, are often transparent, and include cirrus, cirrocumulus, and cirrostratus.

Middle clouds form between 6,500 and 20,000 feet and are denoted by the prefix ALTO. They are made of water droplets and include altostratus and altocumulus.

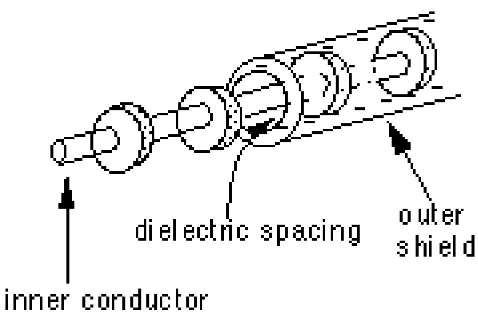
Low clouds are found up to 6,500 feet and include the stratocumulus and nimbostratus clouds. When stratus clouds contact the ground they are called fog.

Vertical clouds, such as cumulus, rise far above their bases and can form at many heights. Cumulonimbus clouds, or thunderheads, can start near the ground and soar up to 75,000 feet.

cloud streets Lines or rows of cumuliform clouds.

Coastal Zone Color Scanner (CZCS) The first spacecraft instrument devoted to measurement of ocean color. Although instruments on other satellites have sensed ocean color, their spectral bands, spatial resolution, and dynamic range were optimized for geographical or meteorological use. In the CZCS, every parameter is optimized for use over water to the exclusion of any other type of sensing. The CZCS flew on the Nimbus-7 spacecraft.

coaxial cable A hollow copper cylinder, or other cylindrical conductor, surrounding a single-wire conductor having a common axis (hence coaxial). The space between the cylindrical shell and the inner conductor is filled with an insulator which may be plastic or mostly air, with supports separating the shell and the inner conductor every inch or so. The cable is used to carry radio frequency signals to or from antennas, etc.



COBOL See Common Business Oriented Language.

comma cloud Band of organized cumuliform clouds that look like a comma from a satellite's perspective. Comma clouds are indicators of heavy storms.

Common Business Oriented Language (COBOL) A computer programming language written for business application.

Compact Disk-Read Only Memory (CD-ROM) Type of computer memory that reads and uses information, but does not allow information to be added, changed, or erased. Digital information is read by laser. CD-ROM does not depend upon any proprietary hardware or software, making it an accessible vehicle for electronic publishing.

computer Electronic machine capable of performing calculations and other manipulations of various types of data, under the control of a stored set of instructions. The machine itself is the hardware; the instructions are the program or software. Depending upon size, computers are called mainframes, minicomputers, and microcomputers. Microcomputers include desk-top and portable personal computers.

condensation Change of a substance to a denser form, such as gas to a liquid. The opposite of evaporation.

conduction The transfer of heat from one substance to another by direct contact. Denser substances are better conductors; the transfer is always from warmer to colder substances.

contrails Condensation trails. Artificial clouds made by the exhaust of jet aircraft.

convection The rising of warm air and the sinking of cool air. Heat mixes and moves air. When a layer of air receives enough heat from the EarthUs surface, it expands and moves upward. Colder, heavier air flows under it which is then warmed, expands, and rises. The warm rising air cools as it reaches higher, cooler regions of the atmosphere and begins to sink. Convection causes local breezes, winds, and thunderstorms.

Coordinated Universal Time (UTC) (aka Greenwich Mean Time [GMT]) Local time at zero degrees longitude at the Greenwich Observatory, England. UTC uses a 24-hour clock, i.e., 2:00 a.m. is 0200 hours, 2:00 p.m. is 1400 hours, midnight is 2400 or 0000 hundred hours.

continent One of the large, continuous areas of the Earth into which the land surface is divided. The six geographically defined continents are politically defined as seven; Africa, Asia, Australia, Europe, North America, South America, and Antarctica.

continental drift See plate tectonics.

Coriolis force The apparent tendency of a freely moving particle to swing to one side when its motion is referred to a set of axes that is itself rotating in space, such as Earth. The acceleration is perpendicular to the direction of the speed of the article relative to the Earth's surface and is directed to the right in the northern hemisphere. Winds are affected by rotation of the Earth so that instead of a wind blowing in the direction it starts, it turns to the right of that direction in the northern hemisphere; left in the southern hemisphere.

coupled system Two or more processes that affect one another.

CPU See central processing unit.

crop calendar The schedule of the maturing and harvesting of seasonal crops.

CRT See cathode ray tube.

cryosphere One of the interrelated components of the Earth's system, the cryosphere is frozen water in the form of snow, permanently frozen ground (permafrost), floating ice, and glaciers. Fluctuations in the volume of the cryosphere cause changes in ocean sea-level, which directly impact the atmosphere and biosphere.

culmination The point at which a satellite reaches its highest position or elevation in the sky, relative to an observer (aka the closest point of approach).

cyclone An area of low pressure where winds blow counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. See anticyclone, wind.

CZCS See Coastal Zone Color Scanner.

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Concepts and Terms

D

- data collection system
- data rate
- decay
- decibel
- declination
- Defense Meteorological Satellite Program
- degree
- delta
- demodulation
- Department of the Interior
- descending node
- desert
- desertification
- detector
- dew
- dew point
- digital image
- digital system
- direct readout
- director
- DIS
- diurnal
- diurnal arc
- Dobson Unit
- doldrums
- Doppler effect

- Doppler radar
- downconverter
- drag
- driven element
- dynamics

data collection system (DCS) DCS units are flown on both GOES and NOAA polar-orbiting spacecraft. They gather and relay data from both mobile and stationary platforms at various locations. DCS units on NOAA satellites can also determine the precise location of moving platforms at the time the data were acquired. See TIROS -N/NOAA satellites.

data rate The amount of information transmitted per unit time.

decay See period decay.

decibel (dB) A tenth of a bel. A unit used to measure the volume of a sound, equal to ten times the common logarithm of the ratio of the intensity of the sound to the intensity of an arbitrarily chosen standard sound. The decibel also is used to measure relative strengths of antenna and amplified signals and always refers to a ratio or difference between two values.

declination The angular distance from the equator to the satellite, measured as positive north and negative south.

Defense Meteorological Satellite Program (DMSP) A U.S. Air Force meteorological satellite program with satellites circling in sun-synchronous orbit. Imagery is collected in the visible- to near-infrared band (0.4 to 1.1 micrometers) and in the thermal-infrared band (about 8 to 13 micrometers) at a resolution of about three kilometers. While some of the data is classified, most unclassified data is available to civilian users.

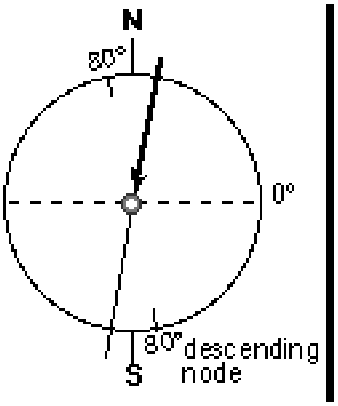
degree A unit of angular measure represented by the symbol o. The circumference of a circle contains 360 degrees. When applied to the roughly spherical shape of the Earth for geographic and cartographic purposes, degrees are each divided into 60 minutes.

delta The fan-shaped area at the mouth or lower end of a river, formed by eroded material that has been carried downstream and dropped in quantities larger than can be carried off by tides or currents.

demodulation The process of retrieving information (data) from a modulated carrier wave, the reverse of modulation.

Department of the Interior (DOI) Responsible for our nationally owned public lands and natural resources, the DOI is chartered to foster the wisest use of our land and water resources, protect fish and wildlife, preserve the environmental and cultural values of national parks and historical places, and provide for the enjoyment of life through outdoor recreation. The department assesses energy and mineral resources and is responsible for assuring that their development is in the best interest of all citizens. The U.S. Geological Survey (USGS) is part of the DOI.

descending node The point in a satellite's orbit at which it crosses the equatorial plane from north to south. See diagram, Keplerian elements.



desert A land area so dry that little or no plant or animal life can survive.

desertification The man-made or natural formation of desert from usable land.

detector A device in a radiometer that senses the presence and intensity of radiation. The incoming radiation is usually modified by filters or other optical components that restrict the radiation to a specific spectral band. The information can either be transmitted immediately or recorded for transmittal at a later time.

dew Atmospheric moisture that condenses after a warm day and appears during the night on cool surfaces as small drops. The cool surfaces cause the water vapor in the air to cool to the point where the water vapor condenses.

dew point The temperature to which air must be cooled for saturation to occur, exclusive of air pressure or moisture content change. At that temperature dew begins to form, and water vapor condenses into liquid.

digital image An analog image converted to numerical form so that it can be stored and used in a computer. the image is divided into a matrix of small regions called picture elements or pixels. At sub-satellite point each pixel represents a specific amount of area. For example, in APT each pixel represents 4.1 kilometers. Each pixel has a numerical value or data number value, quantifying the radiance of the image at that spot. The data number value of each pixel usually represents a value between black and white, i.e., shades of gray.

digital system A system in which information is transmitted in a series of pulses. The source is periodically sampled, analyzed, and converted or coded into numerical values and transmitted. Digital transmissions typically use the *binary* coding used by computers so most data is in appropriate form, but verbal and visual communication must be converted. Many satellite transmissions use digital formats because noise will not interfere with the quality of the end product, producing clear and higher-resolution imagery.

direct readout The capability to acquire data directly from environmental satellites via an Earth station. Data can be acquired from *NOAA* and other nations' environmental satellites, which offer weather information from *geostationary* and *polar-orbiting satellites*.

director Parasitic element(s) of a VHF antenna located forward of the driven element. See antenna.

DIS Data and Information System.

diurnal Performed in twenty-four hours, such as the diurnal revolution of the Earth.

diurnal arc The apparent arc described by heavenly bodies from their rising to their setting.

Dobson Unit The standard way to express ozone amounts in the *atmosphere*. One DU is 2.7 x 10 exp 16 (10 to the 16th power) ozone molecules per square centimeter. One Dobson unit refers to a layer of ozone that would be 0.001 cm thick under conditions of standard temperature (0 degree C) and pressure (the average pressure at the surface of the Earth). For example, 300 Dobson units of ozone brought down to the surface of the Earth at 0 degree C would occupy a layer only 0.3 cm thick in a column. Dobson was a researcher at Oxford University who, in the 1920s, built the first instrument (now called the Dobson meter) to measure total ozone from the ground.

doldrums Region near the equator characterized by low pressure and light shifting winds. See Wind.

doppler effect (aka Doppler shift) The apparent change in frequency of sound or light waves, varying with the relative velocity of the source and the observer. If the source and observer draw closer together, the frequency is increased. Named for Christian Doppler, Austrian mathematician and physicist (1803-1853).

Doppler radar The weather radar system that uses the Doppler shift of radio waves to detect air motion that can result in tornadoes and precipitation, as previously-developed weather radar systems do. It can also measure the speed and direction of rain and ice, as well as detect the formation of tornadoes sooner than older radars.

downconverter Any radio frequency circuit that converts a higher frequency to a lower frequency. This enables signal processing by a receiver. A typical downconverter will fearture one or more states of *RF* preamplification, a mixer where the frequency conversion occurs, a local oscilator chain, and often one or more intermediate frequency preamplifiers to minimize the effect of line losses between the converter and the receiver.

drag (aka N1) A retarding force caused by the Earth's atmosphere. Thus by definition, drag will act opposite to the vehicle's instantaneous velocity vector with respect to the atmosphere. The magnitude of the drag force is directly proportional to the product of the vehicle's cross-section area, its drag coefficient, its velocity, and the atmospheric density, and inversely proportional to its mass. The effect of drag is to cause the orbit to decay, or spiral down-ward. A satellite of very high mass and very low cross-sectional area, and in a very high orbit, may be very little affected by drag, whereas a large satellite of low mass, in a low altitude orbit may be affected very strongly by drag. Drag is the predominant force affecting satellite lifetime.

driven element See antenna.

dynamics The study of the action of forces on bodies and the changes in motion they produce.

Click here to return to Introduction page.

Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

E

- Earth Observing System
- Earth Observing System Data & Information system
- Earth Probes
- Earth Radiation Budget Experiment
- Earth station
- Earth system
- Earth system science
- eccentricity
- eclipse
- eclipse blindness
- ecology
- ecosystem
- electromagnetic radiation
- electromagnetic spectrum
- electromagnetic wave
- electromotive
- electromotive force
- element set
- elevation
- elliptical orbits
- El Niño
- ELT
- energy budget
- ENSO
- environment
- EOS

- EOSDIS
- EPA
- ephemeris
- EPIRB
- epoch
- equator
- ERBE
- ESA
- eutrophication
- evaporation
- exosphere
- external forcing

Earth Observing System (EOS) A series of small- to intermediate-sized spacecraft that is the centerpiece of NASA's *Mission to Planet Earth (MTPE)*. Planned for launch beginning in 1998, each of each of the EOS spacecraft will carry a suite of instruments designed to study global climate change. MTPE will use space-, aircraft-, and ground-based measurements to study our environment as an integrated system. Designing and implementing the MTPE is, of necessity, an international effort. The MTPE program involves the cooperation of the U.S., the European Space Agency (ESA), and the Japanese National Space Development Agency (NASDA). The MTPE program is part of the U.S. interagency effort, the *Global Change Research Program*.

EOS Research

Spacecraft	Research purpose
EOS-AM1 (1998)	characterization of land and ocean surfaces sea-surface temperature terrestrial and ocean productivity clouds, aerosols, and radiative balance
EOS-COLOR (1998)	ocean color and productivity
EOS-AERO1 (2000)	atmospheric aerosols and ozone
EOS-PM1 (2000)	clouds, precipitation, radiative balance, terrestrial snow, and sea ice sea surface temperature terrestrial and ocean productivity atmospheric temperature and moisture
EOS-ALT1 (2002)	ocean circulation, ice sheet mass balance, and land-surface topography
EOS-CHEM1 (2002)	atmospheric chemical species and their transformations solar radiation

projected year of launch shown in parentheses

Earth Obsreving System Data & Informatio System (EOSDIS) The system that will manage a dataset of Earth science observations to be collected over a 15-year period. Existing data indicates that the Earth is changing, and that human activity increasingly contributes to this change. To monitor these changes, a baseline of "normal" performance characteristics must be obtained. For the Earth, these baseline characteristics must cover a global scale and a long enough period that the variation caused by seasonal changes and other cyclical or periodic events (e.g., *El Niño* and the *solar cycle*) may be included in the analyses. The baseline characteristics also must enable scientists to quantify processes that govern the Earth's system. Functionally, EOSDIS will provide computing and networking facilities supporting EOS research activities, including data interpretation and modeling; processing, distribution, and archiving of EOS data; and command and control of EOS observatories.

Earth Probes Discipline-specific satellites and instruments that will be used by *NASA* to obtain observations before the launch of EOS spacecraft. Generally smaller than the EOS satellites and instruments, Earth Probes are planned to complement the broad environmental measurements from EOS with highly focused studies in areas such as tropical rainfall (TRMM), ocean productivity (SeaWiFS), atmospheric ozone (TOMS), and ocean surface winds (NSCAT).

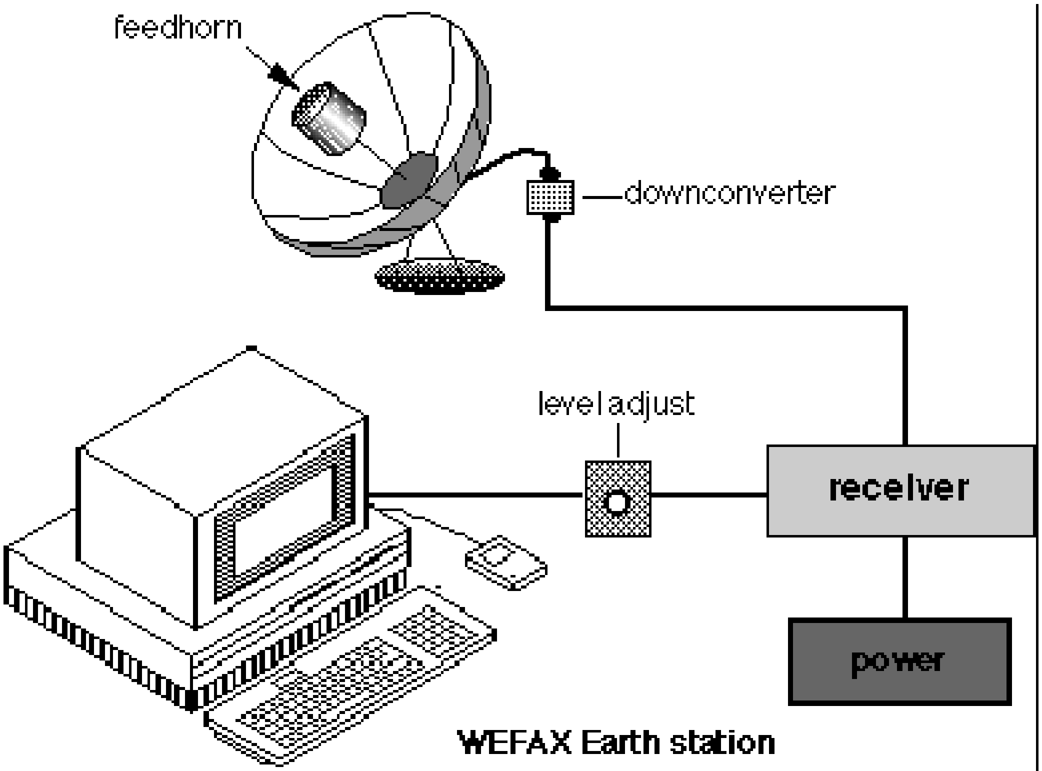
Earth Radiation Budget Experiment (ERBE) An experiment to obtain data to study the average radiation budget of the Earth and determine the energy transport gradient from the equator to the poles. Three satellites were flown in different orbits to obtain the data: the Earth Radiation Budget Satellite, ERBS (launched in October 1984), NOAA-9 (launched in December 1984), and NOAA-10 (launched in September 1986). See [Television and Infrared Observation (TIROS).]

Earth station (aka ground station) Hardware necessary to acquire data directly from environmental satellites. The WEFAX Earth station diagram illustrates a basic ground station configuration for obtaining direct readout data from geostationary environmental (weather) satellites. (See diagram--WEFAX Earth station.)

Earth system The Earth regarded as a unified system of interacting components, including geosphere (land), atmosphere (air), hydrosphere (water and ice), and biosphere (life).

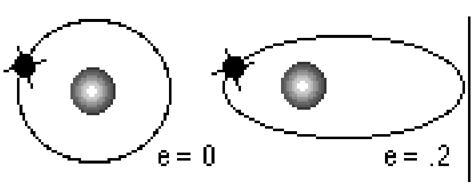
Earth's Interacting Components	
geosphere	Physical elements of the Earth's surface, crust, and interior. Processes in the geosphere include continental drift, volcanic eruptions, and earthquakes.
atmosphere	Thin layer of gas or air that surrounds the Earth. Processes in the atmosphere include winds, weather, and the exchange of gases with living organisms.
hydrosphere	Water and ice on or near the surface of the Earth. Includes water vapor in clouds; ice caps and glaciers; and water in the oceans, rivers, lakes, and aquifers. Processes in the hydrosphere include the flow of rivers, evaporation, and rain.
biosphere	The wealth and diversity of living organisms on the Earth. Processes in the biosphere include life and death, evolution, and extinction.

Earth system science An integrated approach to the study of the Earth that stresses investigations of the interactions among the Earth's components in order to explain Earth dynamics, evolution, and global change.



eccentricity (aka ecce or E0 or e) One of six Keplerian elements, it describes the shape of an orbit. In the Keplerian orbit model, the satellite orbit is an ellipse, with eccentricity defining the "shape" of the ellipse. When e=0, the ellipse is a circle. When e is very near 1, the ellipse is very long and skinny.

eccentricity
e = 0 = > circular orbit
0 < e < 1 = > elliptical orbit
e = 1 = > parabolic orbit
e > 1 = > hyperbolic orbit



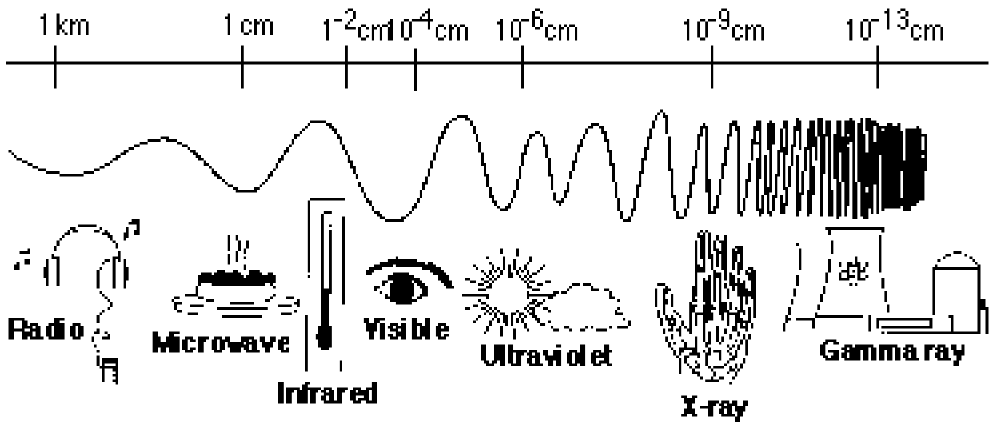
eclipse The partial or total apparent darkening of the sun when the moon comes between the sun and the Earth (solar eclipse), or the arkening of the moon when the full moon is in the Earth's shadow (lunar eclipse).

eclipse blindness Focus-point type of vision loss caused by looking at the sun for too long a time, which can burn a hole in the retina of the eye.

ecology Science dealing with the interrelationships between living organisms and their environments.

ecosystem Any natural unit or entity including living and non-living parts that interact to produce a stable system through cyclic exchane of materials.

eletromagnetic radiation Energy propagated as time-varying electric and magnetic fields. These two fields are inextricably linked as a single entity since time-varying electric fields produce time-varying magnetic fields and vice versa. Light and radar are examples of electromagnetic radiation differing only in their wavelengths (or frequency). Electric and magnetic fields propagate through space at the speed of light.



electromagnetic spectrum The entire range of radiant energies or wave frequencies from the longest to the shortest wavelengths--the categorization of solar radiation. Satellite sensors collect this energy, but what the detectors capture is only a small protion of the entire electromagnetic spectrum. The spectrum usually is divided into seven sections: radio, microwave, infrared, visible, ultraviolet, x-ray, and gamma-ray radiation. See diagram above.

electromagnetic wave Method of travel for radiant energy (all energy is both particles and waves), so called because radiant energy has both magnetic and electrical properties. electromagnetic waves are produced when electric charges change their motion. Whether the frequency is high or low, all electromagnetic waves travel at 300,000,000 meters per second.

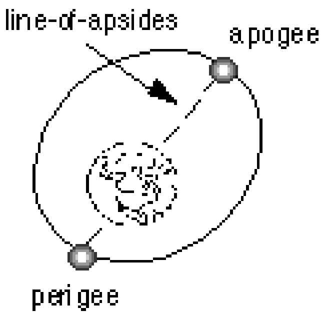
electromotive Producting an electric current through differences in potential.

electromotive force The force that can alter the motion of electricity, measured in terms of the energy per unit charge imparted to electricity passing through the source of this force. Electromotive force causes current flow in a circuit.

element set (aka Keplerian elements, classical elements, satellite elements) Specific information used to define and locate a particular satellite. The set includes the catalog number; epoch year, day, and fraction of day; period decay rate; argument of perigee; inclination, eccentricity; right ascension of the ascending node; mean anomaly; mean motion; revolution number at epoch; and element set number. This data is contained in the two-line orbital elements provided by NASA in the NASA Prediction Bulletin. See Keplerian elements.

elevation The angle at which an antenna must be pointed above the horizon for optimal reception from a spacecraft.

elliptical orbits Bodies in space orbit in elliptical rather than circular orbits because of factors such as *gravity* and *drag*. The point where the orbiting satellite is closest to Earth is the *perigee*, sometimes called peri-apsis or perifocus. The point where the satellite is farthest from Earth is called *apogee*, apoapsis, or apifocus. A line drawn from perigee to *apogee* is the line-of-apsides, sometimes called the major-axis of the ellipse. It's simply a line drawn through the ellipse the long way.



El Niño A warming of the surface waters of the eastern equatorial Pacific that occurs at irregular intervals of 2-7 years, usually lasting 1-2 years. Along the west coast of South America, southerly winds promote the upwelling of cold, nutrient-rich water that sustains large fish populations, that sustain abundant sea birds, whose droppings support the fertilizer industry. Near the end of each calendar year, a warm current of nutrient-pool tropical water replaces the cold, nutrient-rich surface water. Because this condition often occurs around Christmas, it was named El Niño (Spanish for boy child, referring to the Christ child). In most years the warming last only a few weeks or a month, after which the weather patterns return to normal and fishing improves. However, when El Niño conditions last for many months, more extensive ocean warming occurs and economic results can be disastrous. El Niño has been linked to wetter, colder winters in the United States; drier, hotter summers in South America and Europe; and drought in Africa. See ENSO.

ELT Emergency Locator Transmitter. See Search and Rescue.

energy budget A quantitative description of the energy exchange for a physical or ecological system. The budget includes terms for radiation, conduction, convection, latent heat, and for sources and sinks of energy.

ENSO (El Niño-Southern Oscillation) Interacting parts of a single global system of climate fluctuations. ENSO is the most prominent known source of interannual variability in weather and climate around the world, though not all areas are affected. The Southern Oscillation (SO) is a global-scale seesaw in atmospheric pressure between Indonesia/North Australia, and the southeast Pacific. In major warm events El Niño warming extends over much of the tropical Pacific and becomes clearly linked to the SO pattern. Many of the countries most affected by ENSO events are developing countries with economies that are largely dependent upon their agricultural and fishery sectors as a major source of food supply, employment, and foreign exchange. New capabilities to predict the onset of ENSO event can have a global impact. While ENSO is a natural part of the Earth's climate, whether its intensity or frequency may change as a result of global warming is an important concern.

environment The complex of physical, chemical, and biological factors in which a living organism or community exists.

EOS See Earth Observing System.

EOSDIS See Earth Observing System Data and Information System.

EPS (Environmental Protection Agency) U.S. agency that ensures: Federal environmental laws are implemented and enforced effectively; U.S. policy--both foreign and domestic--fosters the integration of economic development and environmental protection so that economic growth can be sustained over the long term; public and private decisions affecting energy, transportation, agriculture, industry, international trade, and natural resources fully integrate considerations of environmental quality; national efforts to reduce environmental risk are based on the best available scientific information communicated clearly to the public; everyone in our society recognizes the value of preventing pollution before it is created; people have the information and incentives they need to make environmentally-responsible choices in their daily lives; and schools and community institutions promote environmental stewardship as a national ethic.

ephemeris A tabulation of a series of points that define the position and motion of a satellite. See *Keplerian elements*.

EPIRB Emergency Position Indicating Radio Beacon. See Search and Rescue.

epoch Epoch specifies the time of a particular description of a satellite orbit. See Keplerian elements.

An imaginary circle around the Earth that is everywhere equally distant (90 degrees) from the North Pole and the South Pole. The equator is a great circle and defines latitude 0 degree.

ERBE See Earth Radiation Budget Experiment.

ESA European Sapce Agency.

eutrophication The process whereby a body of water becomes rich in dissolved nutrients through natural or man-made processes. This often results in a deficiency of dissolved oxygen, producing an environment that favors plant over animal life.

evaporation Change from a liquid (more dense) to a vapor or gas (less dense) from. When whater is heated it becomes a vapor that increases *humidity*. Evaporation is the opposite of *condensation*.

exosphere The uppermost layer of the *atmosphere*, its lower boundary is estimated at 500 km to 1000 km above the Earth's surface. It is only from the exosphere that atmospheric gases can, to any appreciable extent, escape into outer space.

external forcing Influence on the *Earth system* (or one of its components) by an external agent such as *solar radiation* or the impact of extraterrestrial bodies such as meteorites.

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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

F

FAA Federal Aviation Administration.

facsimile A process by which graphic or photographic information is transmitted or recorded by eletronic means.

false color See digital image.

Fahrenheit Temperature scale designed by the German scientist Gabriel Fahrenheit in 1709, based upon water freezing at 32 degrees fahrenheit and water boiling at 212 degrees fahrenheit under standard atmospheric pressure. Compare with *centrigrade*.

far infrared Electromagnetic radiation, longer than the thermal infrared, with wavelengths between about 25 and 1000 micrometers. See electromagnetic spectrum.

feedhorn A metallic cylinder closed at one end, used to obtain and direct *radio frequency (RF)* energy reflected from a satellite dish. It acts as a wave guide at microwave frequencies. RF energy inside the horn is picked up by a small probe; once inside the horn, the wavelength (energy) of the microwave radiation changes to a *guided wave*.

FEMA U.S. Federal Emergency Management Agency.

Feng Yun Chinese geostationary environmental satellite that was destroyed by an explosion before launch in April 1994. The name Feng Yun, meaning Wind and Cloud, was originally applied to the Chinese *polar-orbiting* environmental satellite launched in September 1991 (Feng Yun 1-2), which offered direct readout services. The Chinese polar-orbiter program has since been abandoned.

field The set of influences (electricity, magnetism, gravity) that extend throughout space.

field of view The range of angles that are scanned or sensed by a system or instrument, measured in degrees of arc.

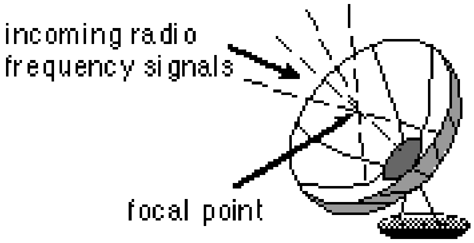
filter Device that while selectively passing desired frequencies removes undesired ones.

FM See frequency modulation.

focal length

1. In optics, the distance--usually expressed in millimeters--from the principal point of a lens or concave mirror to its *focal point*.
2. The distance, measured from the center of the surface of a parabolic or spherical reflector (e.g., *satellite dish*) where RF energy is brought to essential point focus.

focal point The area where weak signals collected by a *satellite dish*, concentrated into a smaller receiving area, converge.



fog A cloud on the ground.

fossil Hardened remains or traces of plant or animal life from a previous geological period preserved in the Earth's crust.

fossil fuel Any hydrocarbon deposit that can be burned for heat or power, such as petroleum, coal, and natural gas.

frame A single image or picture. A single complete vertical scan of the cathode ray tube (CRT).

free radicals Atomic or molecular species with unpaired electrons or an otherwise open shell configuration, usually very reactive. Specific to atmospheric chemistry, free radicals are: short-lived, highly reactive, intermediate species produced by dissociation of the source molecules by solar ultraviolet radiation or by reactions with other stratospheric constituents. Free radicals are the key to intermediate species in many important *stratospheric*chain reactions in which an *ozone* molecule is destroyed and the radical is regenerated. See ozone

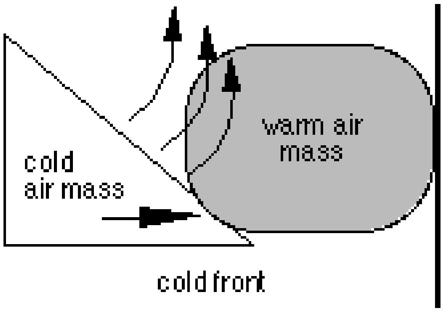
frequency (F) Number of cycles and parts of cycles completed per second. F=1/T, where T is the length of one cycle in seconds.

frequency division multiplexing The combining of a number of signals to share a medium by dividing is into different frequency bands for each signal. See signal.

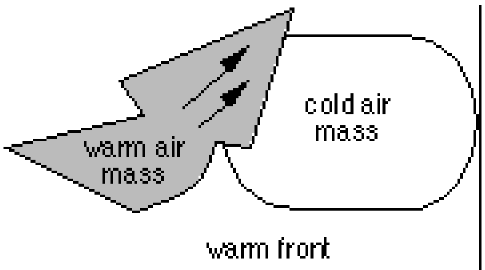
frequency modulation (FM) The instantaneous variation of the frequency of a carrier wave in response to changes in the amplitude of a modulating signal. As applied to *APT*, the radio signal from the satellite is broadcast on an FM transmitter and received on the ground on an FM radio receiver. See frequency division multiplexing, signal.

front A boundary between two different air masses. The difference between two air masses sometimes is unnoticeable. But when the colliding air masses have very different temperatures and amounts of water in them, turbulent weather can erupt.

A cold front occurs when a cold air mass moves into an area occupied by a warmer air mass. Moving at an average speed of about 20 mph, the heavier cold air moves in a wedge shape along the ground. Cold fronts bring lower temperatures and can create narrow bands of violent thunderstorms. In North America, cold fronts form on the eastern edges of high pressure systems.



A warm front occurs when a warm air mass moves into an area occupied by a colder air mass. The warm air is lighter, so it flows up the slope of the cold air below it. Warm fronts usually form on the eastern sides of low pressure systems, create wide areas of clouds and rain, and move at an average speed of 15 mph.



When a cold front follows and then overtakes a warm front (warm fronts move more slowly than cold fronts) lifting the warm air off the ground, an *occluded front* forms.

frost Water condensation occurring on surfaces below freezing. Condensing water turns to ice.

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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

G

- Gaia hypothesis
- gain
- geodesy
- Geographic Information System
- geoid
- geosphere
- geostationary
- Geostationary Meteorological Satellite
- geosynchronous
- glacier
- Global Change Research Program
- global measurement
- global variables
- GMS
- GOES
- GOES 1/GOES 8
- GOES NEXT
- grayscale
- greenhouse effect
- greenhouse gas
- Greenwich Mean Time
- gross feature map
- ground control
- ground station
- ground track
- GSFC

- guided wave
- gulf
- gulf stream

Gaia hypothesis The hypothesis that the Earth's *atmosphere*, *biosphere*, and its living organisms behave as a single system striving to maintain a stability that is conductive to the existence of life.

gain The increase in signal power produced by an amplifier, usually expressed in *decibels* as the ratio of the output to the input. A measure of the effectiveness of a directional antenna as compared to a non-directional antenna. See antenna.

geodesy A branch of applied mathematics concerned with measuring the shape of the Earth and describing variations in the Earth's gravity field.

Geographic Information System (GIS) A system for archiving, retrieving, and manipulating data that has been stored and indexed according to the geographic coordinates of its elements. The system generally can utilize a variety of data types, such as imagery, maps. table, etc.

geoid A surface of constant gravitational potential around the Earth--an averaged surface perpendicular to the force of gravity.

geosphere The physical elements of the Earth's surface crust, and interior.

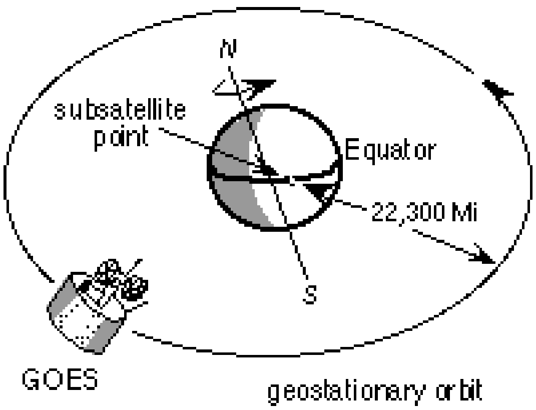
geostationary Describes an orbit in which a satellite is always in the same position (appears stationary) with respect to the rotating Earth. The satellite travels around the Earth in the same direction, at an altitude of approximately 35,790 km (22,240 statute miles) because that produces an orbital period equal to the period of rotation of the Earth (actually 23 hours, 56 minutes, 04.09 seconds). A worldwide network of operational geostationary meteorological satellites provides visible and infrared images of Earth's surface and atmosphere. The satellite systems include the U.S. *GOES*, *METEOSAT*(launched by the European Space Agency and operated by the European Weather Satellite Organization-EUMETSAT), the Japanese *GMS* and most commercial, telecommunications satellites. See Clarke Belt.

Geostationary Meteorological Satellite (GMS) Japan's geostationary weather satellite.

Geostationary Operational Environmental Satellite (GEOS) NASA-developed, NOAA-operated series of satellites that:

- provide continuous day and night weather observations;
- monitor severe weather events such as hurricanes, thunderstorms, and flash floods;
- relay environmental data from surface collection platforms to a processing center;
- perform facsimile transmissions of processed weather data to low-cost receiving stations;
- monitor the Earth's magnetic field, the energetic particle flux in the satellite's vicinity, and x-ray emissions from the sun;
- detect distress signals from downed aircraft and ships.

GOES observes the U.S. and adjacent ocean areas from vantage points 35,790 (22,240 miles) above the equator at 75 degrees west and 135 degrees west. GOES satellites have an equatorial, Earth-synchronous orbit with a 24-hour period, a visible resolution of 1 km, an IR resolution of 4 km, and a scan rate of 1864 statute miles in about three minutes. See geostationary. The transmission of processed weather data (both visible and infrared) by GOES is called weather facsimile (WEFAX). GOES WEFAX transmits at 1691+ MHz and is accessible via a ground station with a satellite dish antenna.



GOES carries the following five major sensor systems:

1. The imager is a multispectral instrument capable of sweeping simultaneously one visible and four infrared channels in a north-to-south swath across an east-to-west path, providing full disk imagery once every thirty minutes.
2. The sounder has more spectral bands than the imager for producing high quality atmospheric profiles of temperature and moisture. It is capable of stepping one visible and eighteen infrared channels in a north-to-south swath across an east-to-west path.
3. The Space Environment Monitor (SEM) measures the condition of the Earth's magnetic field, the solar activity and radiation around the spacecraft, and transmits these data to a central processing facility.
4. The Data Collection System (DCS) receives transmitted meteorological data from remotely located platforms and relays the data to the end-users.
5. The Search and Rescue Transponder can relay distress signals at all times, but cannot locate them. While only the polar-orbiting satellite can locate distress signals, the two types of satellites work together to create a comprehensive search and rescue system.

geosynchronous (aka GEO) Synchronous with respect to the rotation of the Earth. See geostationary.

glacier A multi-year surplus accumulation of snowfall in excess of snowmelt on land and resulting in a mass of ice at least 0.1 km2 in area that shows some evidence of movement in response to gravity. A glacier may terminate on land or in water. Glacier ice is the largest reservoir of fresh water on Earth, and second only to the oceans as the largest reservoir of total water. Glaciers are found on every continent except Australia.

Global Change Research Program (GCRP) The USGCRP is a government-wide program whose goal is "to establish a scientific basis for national and international policy-making relating to natural and human-induced changes in the global Earth system." Mission To Planet Earth is NASA's central contribution to the U.S. Global Change Research Program.

The Global Change Research Program coordinates and guides the efforts of federal agencies. The program examines such questions as, is the Earth experiencing global warming? Is the depletion of the ozone layer expanding? How do we determine and understand the causes of global climate changes? Are they reversible? What are the implications for human needs and activities?

global measurement All of the activities required to specify a global variable, such as ozone. These activities range from data acquisition to the generation of a data-analysis product, and include estimates of the uncertainties in that product. A global measurement often will consist of a combination of observations from a spacecraft instrument (required for global coverage) and measurements *in situ* (needed to provide reference points for long-term accuracy).

global variables Functions of space and time that describe the large scale state and evolution of the Earth system. The Earth system's geosphere, hydrosphere, atmosphere, and biosphere and their components are, or potentially are, global variables.

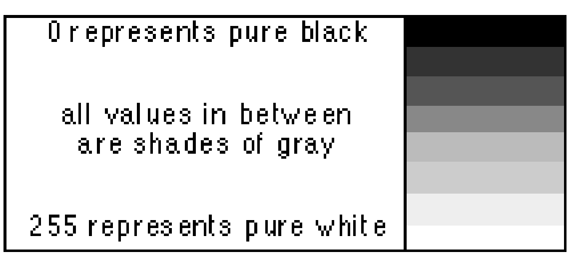
GMS See *Geostationary Meteorological Satellite.*

GOES See *Geostationary Operational Environmental Satellite.*

GOES I/GOES 8 NOAA geostationary satellite launched in April 1994 (alphabetical designators are used while on the ground and before geostationary orbit, after it achieves geostationary orbit it became GOES 8). GOES 8 is the first in a series of five new geostationary satellites that will ensure dual-satellite coverage of the U.S. into the next century, and will provide better advanced warnings of thunderstorms, flash floods, hurricanes, and other severe weather. GOES 8 will also contribute important information to a new flood and water management system which will assist decision-makers with the allocation of precious western water resources.

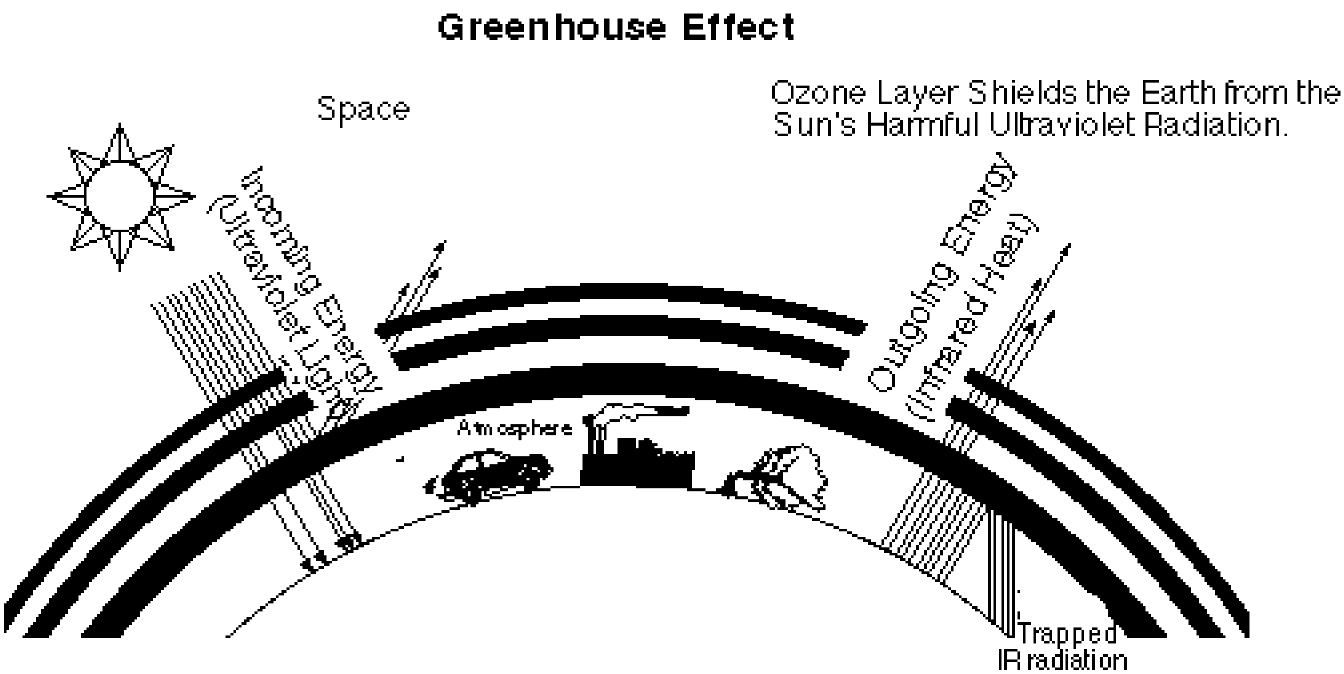
GOES NEXT The next generation of NOAA geostationary satellites, scheduled for launch beginning sometime after 2003. Currently in the planning phase, these satellites will follow the series of five geostationary satellites which are being launched beginning in 1994. See GOES I

grayscale Environmental satellite scanners, rather than photographing a scene, scan a scene line-by-line measuring light or heat levels and transmitting this information as a video image via an amplitude modulated (AM) subcarrier contained in the satellite's FM signal. The video image--a 2400 Hz tone--is amplitude modulated to correspond to the light and dark areas sensed, with the louder portion of the tone representing the lighter areas of the image and the lower portion of the tone representing the darker areas of the image. Intermediate volumes form the shades of the gray scale (up to 256 shades) needed to complete the image. This is an analog type of data transmission, and enables the assessment of such features as heat, light, temperature, and cloud heights.



greenhouse effect Process by which significant changes in the chemistry of Earth's atmosphere may enhance the natural process that warms our planet and elevates temperatures. If the effect is intensified and Earth's average temperatures change, a number of plant and animal species could be threatened with extinction.

Certain gaseous components of the atmosphere, called greenhouse gases, transmit the visible portion of solar radiation but absorb specific spectral bands of thermal radiation emitted by the Earth. The theory is that terrain absorbs radiation, heats up, and emits longer wavelength thermal radiation that is prevented from escaping into space by the blanket of carbon dioxide and other greenhouse gases in the atmosphere. As a result, the climate warms. Because atmospheric and oceanic circulations play a central role in the climate of the Earth, improving our knowledge about their interaction becomes essential.



greenhouse gas A gaseous component of the atmosphere contributing to the greenhouse effect. Greenhouse gases are transparent to certain wavelengths of the sun's radiant energy, allowing them to penetrate deep into the atmosphere or all the way into the Earth's surface. Greenhouse gases and clouds prevent some of infrared radiation from escaping, trapping the heat near the Earth's surface where it warms the lower atmosphere. Alteration of this natural barrier of atmospheric gases can raise or lower the mean global temperature of the Earth.

Greenhouse gases include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, and water vapor. Carbon dioxide, methane, and nitrous oxide have significant natural and human sources while only industries produce chlorofluorocarbons. Water vapor has the largest greenhouse effect, but its concentration in the troposphere is determined within the climate system. Water vapor will increase in response to global warming, which in turn may further enhance global warming.

Key Greenhouse Gases
water vapor
ozone
carbon dioxide
methane
nitrous oxide
chlorofluorocarbons (CFCs)

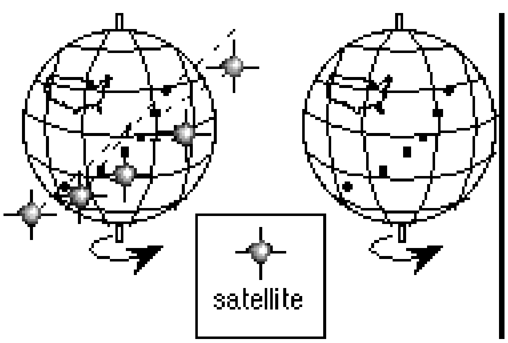
Greenwich Mean Time (GMT) See Coordinated Universal Time.

gross feature map Map that displays geographic characteristics rather than political boundaries.

ground control (points) Identifiable points on the ground whose locations on the surface of the Earth are accurately known for use as geodetic references in mapping, charting, and other related mensuration applications.

ground station See Earth station.

ground track The inclination of a satellite, together with its orbital altitude and the period of its orbit, creates a track defined by an imaginary line connecting the satellite and the Earth's center. The intersection on the line with the Earth's surface is the subsatellite point. As the Earth turns on its axis and the satellite orbits overhead, a line is created by the satellite's apparent path over the ground (the series of subsatellite points connected). A geostationary satellite has an inclination of essentially zero, and, because its orbital period exactly matches the Earth's rotation, its ground track is reduced to an apparent stationary point on the equator.



GSFC NASA Goddard Space Flight Center, located in Greenbelt, Maryland. See NASA Centers.

guided wave Electromagnetic or acoustic wave that is constrained within certain boundaries, as in a wave guide (transmission line).

gulf A large arm of an ocean or sea extending into a land mass.

gulf stream A warm, swift ocean current that flows along the coast of the Eastern United States and makes Ireland, Great Britain, and the Scandinavian countries warmer than they would be otherwise.

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Looking at Earth From Space

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Concepts and Terms

H

habitat The area or region where a particular type of plant or animal lives and grows.

hail Precipitation composed of balls or irregular lumps of ice. Hail is produced when large frozen raindrops, or almost any particles, in cumulonimbus clouds act as embryos that grow by accumulating supercooled liquid droplets. Violent updrafts in the cloud carry the particles in freezing air, allowing the frozen core to accumulate more ice. When the piece of hail becomes too heavy to be carried by upsurging air currents it falls to the ground.

hardware The electrical and mechanical components of a system, as opposed to software.

haze Fine dry or wet particles of dust, salt, or other impurities that can concentrate in a layer next to the Earth when air is stable.

heat balance The equilibrium existing between the radiation received and emitted by a planetary system.

Heat Capacity Mapping Mission (HCMM) A two-channel radiometer launched by NASA to measure the thermal properties of the terrestrial surface. It had an application to identify and locate rocks and minerals. One radiometer channel was in the visible to near infrared (0.5-1.1 micrometers), and the other in the thermal infrared (10.5-12.5 micrometers). The instantaneous field of view (IFOV) was about 600 meters.

hemisphere Half of the Earth, usually conceived as resulting from the division of the globe into two equal parts, north and south or east and west.

hertz The international unit of frequency equal to one cycle per second. Radio frequencies are usually expressed in kilohertz/kHz (1,000 cycles per second) or megahertz/MHz (1,000,000 cycles per second).

Hertzian waves Radio waves or other electromagnetic radiation resulting from the oscillations of electricity in a conductor.

high A digital logic state corresponding to a binary "1." See low.

High Resolution Doppler Imager (HRDI) Carried on UARS, it measures stratospheric winds.

High-Resolution Infrared Radiation Sounder (HIRS) Instrument carried by NOAA polar-orbiting satellites that detects and measures energy emitted by the atmosphere to construct a vertical temperature profile from the Earth's surface to an altitude of about 40 km. Measurements are made in 20 spectral regions in the infrared band.

High-Resolution Picture Transmission (HRPT) Real-time, 1.1-kilometer resolution, digital images provided by NOAA's polar-orbiting environmental satellites, containing all five spectral channels and telemetry data transmitted as high-speed digital transmissions. The Advanced Very High Resolution Radiometer (AVHRR) provides the primary imaging system for APT and HRPT. See TIROS

horse latitudes The subtropical latitudes (30-35 degrees), where winds are light and weather is hot and dry. According to legend, ships traveling to the New World often stagnated in this region and had to throw dead horses overboard or eat them to survive, hence the name horse latitudes. See *wind*.

HRDI See *High Resolution Doppler Imager*.

HRPT See *High Resolution Picture Transmission.*

humidity The amount of water vapor in the air. The higher the temperature, the greater the number of water molecules the air can hold. For example: at 60 degrees F (15 degrees C), a cube of air one yard on each side can hold up to 4.48 ounces of water. At 104 degrees F (40 degrees C), the same cube of air can hold up to 17.9 ounces of water.

Relative humidity describes the amount of water in the air compared with how much the air can hold at the current temperature. Example: 50% relative humidity means the air holds half the water vapor that it is capable of holding; 100% relative humidity means the air holds all the water vapor it can. At 100% humidity, no more evaporation can occur until the temperature rises, or until the water vapor leaves the air through condensation. Absolute humidity is the ratio of the mass of water vapor present in a system of moist air to the volume occupied by the mixture, that is, the density of water vapor.

hurricanes Severe tropical storms whose winds exceed 74 mph. Hurricanes originate over the tropical and subtropical North Atlantic and North Pacific oceans, where there is high humidity and light wind. These conditions prevail mostly in the summer and early fall. Since hurricanes can take days or even weeks to form, time is usually available for preventive or protective measures.

From space, hurricanes look like giant pinwheels, their winds circulating around an eye that is between 5 and 25 miles in diameter. The eye remains calm with light winds and often a clear sky.

Hurricanes may move as fast as 50 mph, and can become incredibly destructive when they hit land. Although hurricanes lose power rapidly as soon as they leave the ocean, they can cause high waves and tides up to 25 feet above normal. Waves and heavy flooding cause the most deaths during a hurricane. The strongest hurricanes can cause tornadoes.

hydrochlorofluorocarbon (HCFC) One of a class of compounds used primarily as a CFC substitute. Work on CFC alternatives began in the late 1970s after the first warnings of CFC damage to stratospheric ozone. By adding hydrogen to the chemical formulation, chemists made CFCs less stable in the lower atmosphere enabling them to break down before reaching the ozone layer. However, HCFCs do release chlorine and have contributed more to atmospheric chlorine buildup than originally predicted. Development of non-chlorine based chemical compounds as a substitute for CFCs and HCFCs continues.

hydrologic cycle The pathways through which water is cycled in the terrestrial biosphere.

hydrosphere The totality of water encompassing the Earth, comprising all the bodies of water, ice, and water vapor in the atmosphere.

hygrometer Instrument that measures water vapor content in the air and communicates changes in humidity visibly and immediately through a graph or a dial. There are three types of hygrometers:

- The hair hygrometer uses a human hair as the sensing instrument. The hair lengthens when the air is moist and contracts when the air is dry, but remains unaffected by air temperature. However, the hair hygrometer cannot respond to rapid fluctuations in humidity.
- An electric hygrometer uses a plate coated with carbon. Electrical resistance of the carbon coating changes as the moisture content of the air changes--changes that translate into relative humidity. This type of hygrometer is used frequently in the radiosonde.
- An infrared hygrometer uses a beam of light containing two separate wave lengths to gauge atmospheric humidity. One of the wavelengths is absorbed by water vapor, the other is unaffected, providing an extremely accurate index of water vapor for paths of a few inches or thousands of feet. See psychrometer.

Hz See *Hertz.*

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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

I

- ice shelf
- IFOV
- IGY
- image
- image resolution
- imager
- inclination
- information system
- infrared radiation
- INSAT
- in situ
- insolation
- instantaneous field of view
- integrated circuit
- international date line
- international designator
- international Geophysical Year
- International Space Year
- international system of Units
- ion
- IPS
- IR
- isobars
- isothermal
- isotherms
- isthmus

- ITOS

ice shelf A thick mass of ice extending from a polar shore. The seaward edge is afloat and sometimes extends hundreds of miles into the sea.

IFOV Instantaneous Field of View. See Multispectral Scanner for sample usage.

IGY See *International Geophysical Year*.

image Pictorial representation of data acquired by satellite systems, such as direct readout images from environmental satellites. An image is not a photograph. An image is composed of two-dimensional grids of individual picture elements (pixels). Each pixel has a numeric value that corresponds to the radiance or temperature of the specific ground area it depicts. See gray scale.

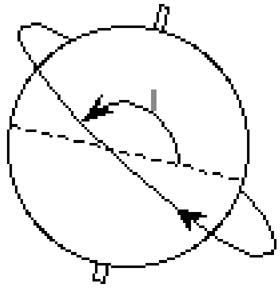
image resolution The area represented by each pixel of a satellite image. The smaller the area represented by a pixel, the more accurate and detailed the image. For example, if a U.S. map and a world map are printed on identically sized sheets of paper, one square inch on the U.S. map will represent far less area and provide for more detail than one square inch on the world map. In this example the U.S. map has higher resolution. APT has a resolution of 4 km, HRPT has a resolution of 1.1 km and WEFAX resolution is 8 km.

imager A satellite instrument that measures and maps the Earth and its atmosphere. Imager data are converted by computer into pictures.

inclination (aka i) One of the six Keplerian elements, it indicates the angle of the orbit plane to the central body's equator. See Keplerian elements for diagram.

The elliptical path of a satellite orbit lies in a plane known as the orbital plane. The orbital plane always goes through the center of the Earth but may be tilted at any angle relative to the equator. Inclination is the angle between the equatorial plane and the orbital plane measured counter-clockwise at the ascending node.

A satellite in an orbit that exactly matches the equator has an inclination of 0 degree, whereas one whose orbit crosses the Earth's poles has an inclination of 90 degrees. Because the angle is measured in a counterclockwise direction, it is quite possible for a satellite to have an inclination of more than 90 degrees. An inclination of 180 degrees would mean the satellite is orbiting the equator, but in the opposite direction of the Earth's rotation. Some sun-synchronous satellites that maintain the same ground track throughout the year have inclinations of as much as 98 degrees. U.S. scientific satellites that study the sun are placed in orbits closer to the equator, frequently at 28 degrees inclination. Most weather satellites are placed in high-inclination orbits so they can oversee weather conditions worldwide. See orbital inclination.



angle of inclination
(measured counterclockwise at the
ascending node)

information system All of the means and mechanisms for data receipt, processing, storage, retrieval, and analysis. Information Systems can be designed for storage and dissemination of a variety of data products--including primary data sets and both intermediate and final analyses--and for an interface providing connections to external computers, external data banks, and system users. To be effective, the design and operation of an information system must be carried out in close association with the primary producers of the data sets, as well as other groups producing integrated analyses or intermediate products.

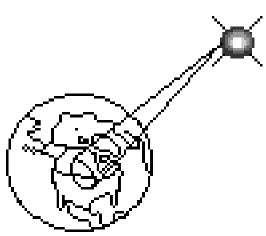
infrared radiation (IR) Infrared is electromagnetic radiation whose wavelength spans the region from about 0.7 to 1000 micrometers (longer than visible radiation, shorter than microwave radiation). Remote sensing instruments work by sensing radiation that is naturally emitted or reflected by the Earth's surface or from the atmosphere, or by sensing signals transmitted from a satellite and reflected back to it. In the visible and near-infrared regions, surface chemical composition, vegetation cover, and biological properties of surface matter can be measured. In the mid-infrared region, geological formations can be detected due to the absorption properties related to the structure of silicates. In the far infrared, emissions from the Earth's atmosphere and surface offer information about atmospheric and surface temperatures and water vapor and other trace constituents in the atmosphere. Since IR data are based on temperatures rather than visible radiation, the data may be obtained day or night.

INSAT Indian National Satellite.

in situ Latin for "in original place." Refers to measurements made at the actual location of the object or material measured. Compare remote sensing.

insolation Solar radiation incident upon a unit horizontal surface on or above the Earth's surface.

instantaneous field of view (IFOV) The field of view of a scanning detector system at a given instant. The range of angles scanned by the system is then called the field of view, or swath width.



Instantaneous field of view

integrated circuit (IC) A solid state electronic circuit that consists of several micro-components constructed to perform a special function.

international date line An imaginary line of longitude 180 degrees east or west of the prime meridian.

international designator An internationally agreed-upon naming convention for satellites. The designator contains the last two digits of the launch year, the launch number of the year, and the part of the launch, i.e., RAS indicates payload, RBS the rocket booster, or second payload, etc.

International Geophysical Year (IGY) (1957P58) The IGY was organized by the scientific community through the International Council of Scientific Unions (ICSU) . It was highlighted by international cooperation in the exploration of world-wide geophysical phenomena and by the inauguration of the space age through the launching of the first satellites (USSR's Sputnik I and US Explorer 1) to study the upper atmosphere and Earth's nearby environment.

International Space Year (ISY) (1992) Designated the first international celebration of humanity's future in the space age. Themes included the global perspective of the space age, discovery, exploration, and scientific inquiry. An important ISY scientific focus was Mission to Planet Earth. A wide range of educational programs and public events emphasized ISY's global perspective.1992 also commemorated the 500th anniversary of Columbus' voyage to the New World and the 35th anniversary of the International Geophysical Year.

International System of Units (SI) The International System of Units prescribes the symbols and prefixes shown in the table to form decimal multiples and submultiples of SI units.

SI prefixes		
Factor	Prefix	Symbol
10^{1}	deka	da
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

The following examples illustrate the use of these prefixes:

0.000,001 meters = 1 micrometer = 1μm
1000 meters = 1 kilometer = 1 km
1,000,000 cycles per second = 1,000,000 hertz = 1 megahertz =1 MHz

ion Atom or molecule that has acquired an electric charge by the loss or gain of one or more electrons.

IPS Inches per second.

IR See *infrared.*

isobars Lines drawn on a weather map joining places of equal barometric pressure.

isothermal Of or indicating equality of temperature.

isotherms Lines connecting points of equal temperature on a weather map.

isthmus Narrow strip of land located between two bodies of water, connecting two larger land areas.

ITOS (Improved TIROS Operational Satellite) Second generation, polar-orbiting, environmental satellites utilized to augment NOAA's world-wide weather observation capabilities. ITOS were launched from 1970 - 1976, but eventually replaced by the third generation of polar-orbiting, environmental satellites TIROS-N (first launched in 1978). See TIROS.

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Concepts and Terms

J

- Japanese National Space Development Agency
- JPL
- jet stream
- joint Education Initiative
- JSC

Japanese National Space Development Agency (NASDA) The agency reports to the Japanese Ministry of Science and Technology.

JPL (Jet Propulsion Laboratory) See NASA Centers.

jet stream Rivers of high-speed air in the atmosphere. Jet streams form along the boundaries of global air masses where there is a significant difference in atmospheric temperature. The jet streams may be several hundred miles across and 1-2 miles deep at an altitude of 8-12 miles. They generally move west to east, and are strongest in the winter with core wind speeds as high as 250 mph. Changes in the jet stream indicate changes in the motion of the atmosphere and weather.

Joint Education Initiative (JEI) The JEI project was developed by USGS, NOAA, NASA, industry, and teachers to enable teachers and students to explore the massive quantities of Earth science data published by the U.S. Government on CD-ROM. JEI encourages a research and analysis approach to science education.

JSC (Johnson Space Center) See NASA Centers

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Concepts and Terms

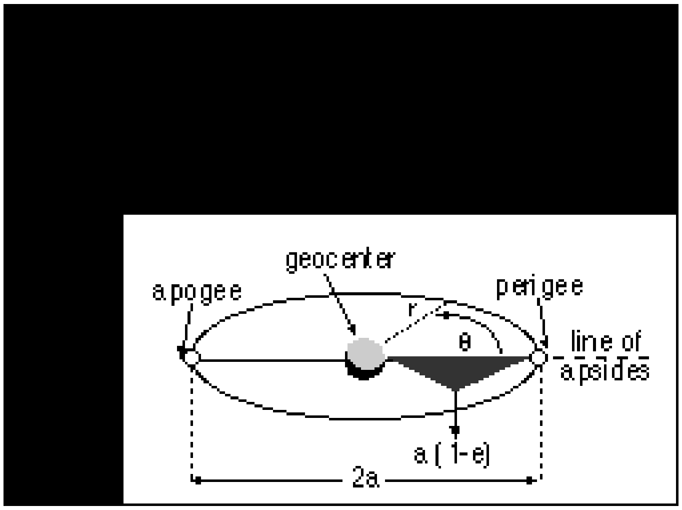
K

- KSC
- Keplerian elements
- Kepler's three laws of motion
- kilohertz
- kilometer
- knot

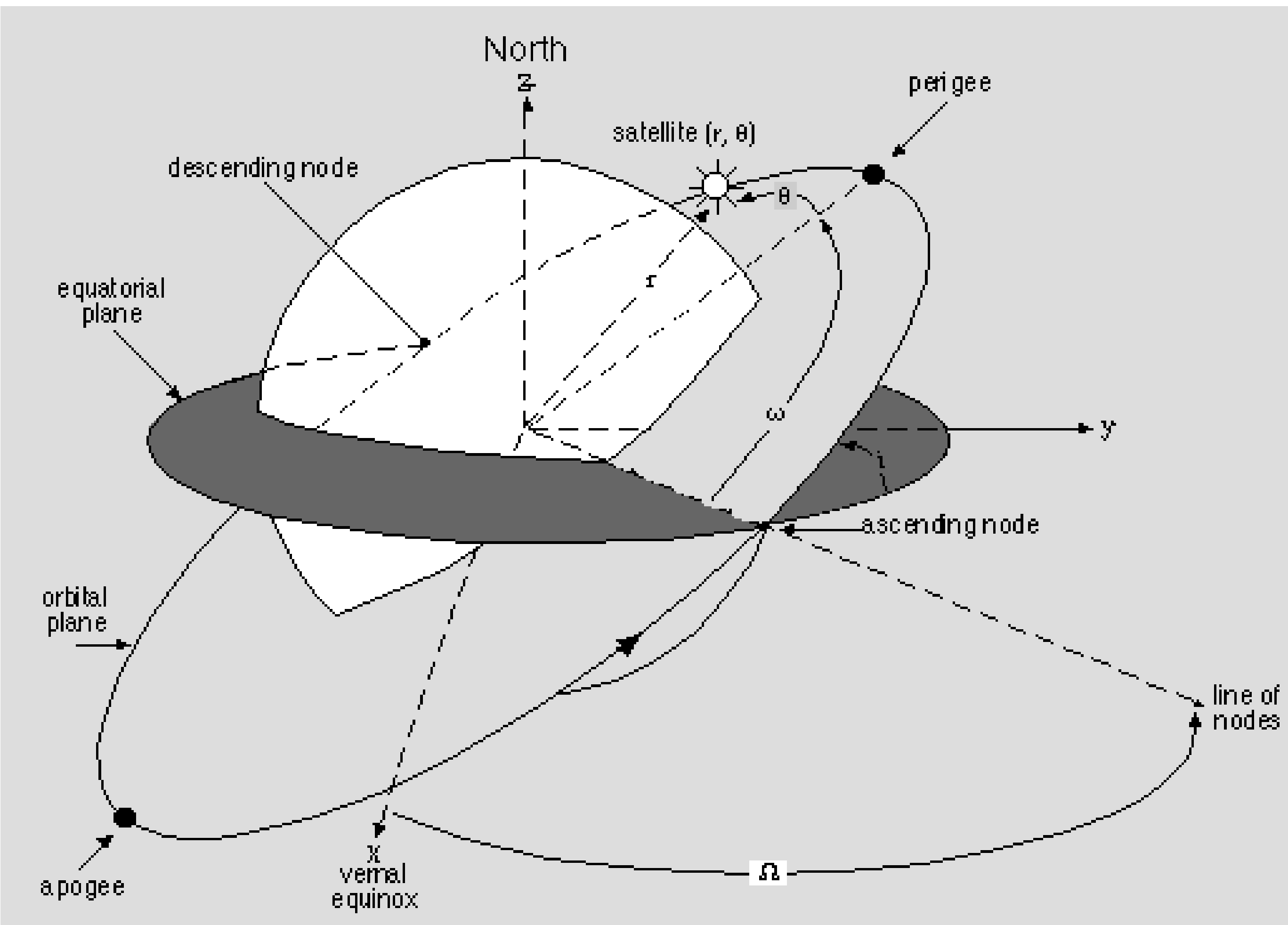
KSC (Kennedy Space Center) See NASA Centers.

Keplerian elements (aka satellite orbital elements) The set of six independent constants which define an orbit--named for Johannes Kepler [1571-1630]. The constants define the shape of an ellipse or hyperbola, orient it around its central body, and define the position of a satellite on the orbit. The classical orbital elements are:

Keplerian elements	
a	semi-major axis, gives the size of the orbit
e	eccentricity, gives the shape of the orbit
i	inclination angle, gives the angle of the orbit plane to the central body's equator
Ω	right ascension of the ascending node, which gives the rotation of the orbit plane from reference axis
ω	argument of perigee gives the rotation of the orbit plane
θ	true anomaly gives the location of the satellite on the orbit



Kepler's three laws of motion Any spacecraft launched into orbit obeys the same laws that govern the motions of the planets around our sun, and the moon around the Earth. Johannes Kepler formulated three laws that describe these motions:



orbital elements		
Element	Conventional Symbol	Symbol used in GSFC Computer Printouts
epoch	epoch	Epoch Time, TO
orbital inclination	i	Inclination, IO
right ascension of ascending node	Ω	R.A.A.N., O0
argument of perigee	ω	(ARGP) Arg Perigee, WO
eccentricity	e	(ecce) Eccentricity, EO or e
mean motion	n	Mean Motion, NO
mean anomally	M	(MA, phase) Mean Anomaly, MO

kilohertz

1. Each planet revolves around the sun in an orbit that is an ellipse with the sun as its focus or primary body. Kepler postulated the lack of circular orbits--only elliptical ones--determined by gravitational perturbations and other factors. Gravitational pulls, according to Newton, extend to infinity, although their forces weaken with distance and eventually become impossible to detect. (See Newton's law of universal gravitation.) Spacecraft orbiting the Earth are primarily influenced by the Earth's gravity and anomalies in its composition, but they also are influenced by the moon and sun and possibly other planets.
2. The radius vector--such as the line from the center of the sun to the center of a planet, from the center of Earth to the center of the moon, or from the center of Earth to the center of gravity of a satellite--sweeps out equal areas in equal periods of time.
3. The square of a planet's orbital period is equal to the cube of its mean distance from the sun times a constant. As extended and generalized, this means that a satellite's orbital period increases with its mean distance from the planet. See Newton's law of universal gravitation and laws of motion.

kilohertz (kHz) One thousand hertz, i.e., one thousand cycles per second.

kilometer (km) Metric unit of distance equal to 3,280.8 feet or .621 statute miles.

knot Unit of speed of one nautical mile (6,076.1 feet) an hour.

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Concepts and Terms

L

lake A body of fresh or salt water entirely surrounded by land.

land breeze A nocturnal coastal breeze that blows from land to sea. In the evening the water may be warmer than the land, causing pressure differences. The land breeze is the flow of air from land to sea equalizing these pressure differences. See sea breeze.

Landsat Land Remote-Sensing Satellite, operated by the U.S. Earth Observation Satellite Company (EOSAT). Commercialized under the Land Remote-Sensing Commercialization Act of 1984, Landsat is a series of satellites (formerly called ERTS) designed to gather data on the Earth's resources in a regular and systematic manner. Objectives of the mission are: land use inventory, geological/mineralogical exploration, crop and forestry assessment, and cartography. Landsat has a spatial resolution of 28.5 meters.

Restructured Federal agency responsibilities for the Landsat program are effective for the acquisition and operation of Landsat 7. New operating policy specifies that NOAA will be responsible for satellites after they are placed in orbit, NASA will be responsible for the development and launch of Landsat 7, and that the U.S. government will provide unenhanced data to users at no cost beyond the cost of fulfilling their data request.

landsats (aka Earth resources satellites) Any land remote-sensing satellites. Includes the U.S. Landsat system and the French SPOT.

LaRC (Langley Research Center) See NASA Centers.

laser (light amplification by stimulated emission of radiation) Active instrument that produces discretely coherent pulses of light (light waves with no phase differences, or with predictable phases differences, are said to be coherent).

laser ranging The use of lasers to measure distances.

latitude (aka the geodetic latitude) The angle between a perpendicular at a location, and the equatorial plane of the Earth.

legend A listing that contains symbols and other information about a map.

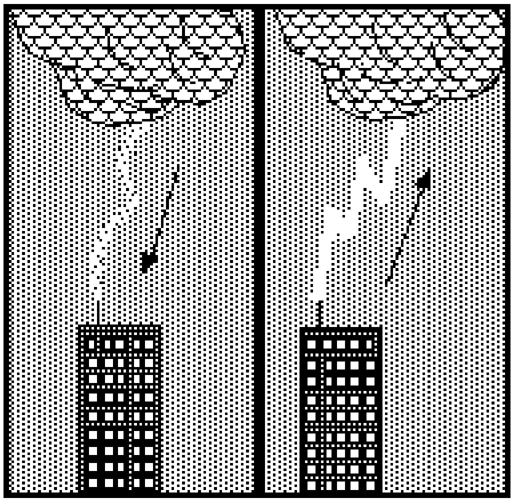
LeRC LeRC (Lewis Research Center) See NASACenters.

light

1. Form of radiant energy that acts upon the retina of the eye, optic nerve, etc., making sight possible. This energy is transmitted at a velocity of about 186,000 miles per second by wavelike or vibrational motion.
2. A form of radiant energy similar to this, but not acting on the normal retina, such as ultraviolet and infrared radiation.

Interplay between light rays and the atmosphere cause us to see the sky as blue, and can result in such phenomena as glows, halos, arcs, flashes, and streamers.

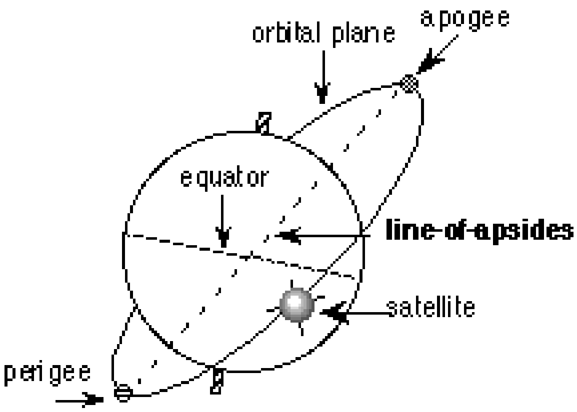
lightning A discharge of atmospheric electricity accompanied by a vivid flash of light. During thunderstorms, static electricity builds up within the clouds. A positive charge builds in the upper part of the cloud, while a large negative charge builds in the lower portion. When the difference between the positive and negative charges becomes great, the electrical charge jumps from one area to another, creating a lightning bolt. Most lightning bolts strike from one cloud to another, but they also can strike the ground. These bolts occur when positive charges build up on the ground. A negative charge called the "faintly luminous streamer" or "leader" flows from the cloud toward the ground. Then a positively charged leader, called the return stroke, leaves the ground and runs into the cloud. What is seen as a lightning bolt is actually a series of downward-striking leaders and upward-striking return strokes, all taking place in less than a second.



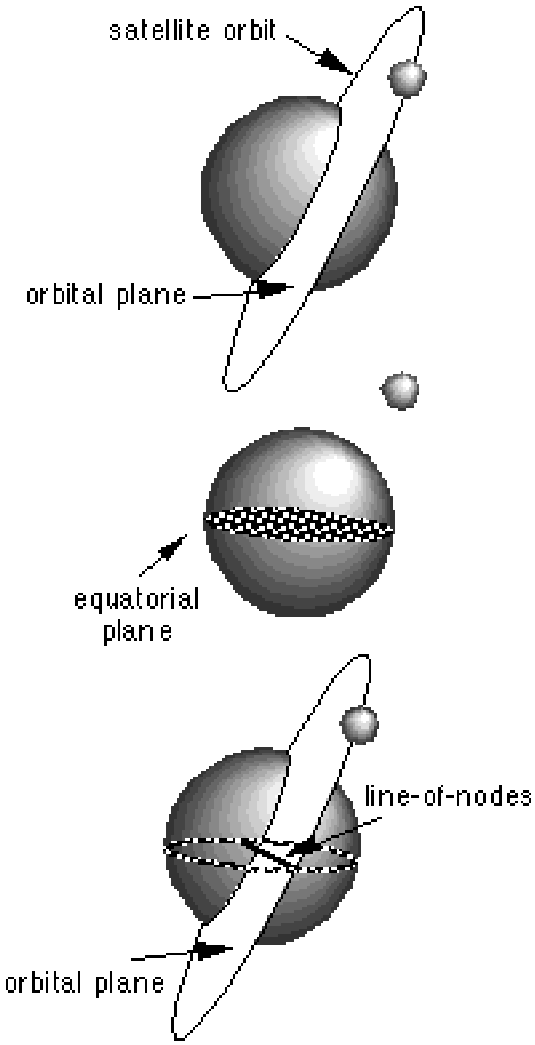
Lightning bolts can heat the air to temperatures hotter than the surface of the sun. This burst of heat makes the air around the bolt expand explosively, producing the sound we hear as thunder. Since light travels a million times faster than sound, we see lightning bolts before we hear their thunderclaps. By counting the seconds between a flash of lightning and the thunderclap and dividing by five, we can determine the approximate number of miles to the lightning stroke. See thunderstorm

limb viewing (occultation) The process of viewing the atmosphere at a tangent to the Earth's surface. The viewing signal, from a star or another satellite, is occulted or obscured by the intervening atmosphere. The absorption of light from the sun or star provides information on the properties of the atmosphere at different heights. Limb viewing instruments can also sense infrared or microwave emitted radiation from the atmosphere.

line-of-apsides line-of-apsides (aka major-axis of the ellipse) The straight line drawn from the perigee (point of orbit closest to Earth) to the apogee (point of orbit farthest from Earth) is the line-of-apsides.



line-of-nodes The line created by the intersection of the equatorial plane and the orbital plane.



line-of-sight Area within which visible contact can be made. For example, NOAA polar-orbiting satellites continuously transmit the APT signal. Radio reception of the APT signal is possible only when the satellite is above the horizon of a particular location (not obstructed by the Earth's surface), with a line-of-sight contact with the satellite.

logarithm Exponent of the power to which it is necessary to raise a fixed number (the base) to produce the given number. For example, the logarithm of 100 (base 10) is 2 because 10^2 equals 100.

longitude The angular distance from the Greenwich meridian (0 degree), along the equator. This can be measured either east or west to the 180th meridian (180 degrees) or 0 degree to 360 degrees W.

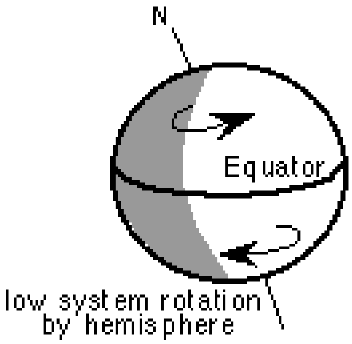
loss of signal (LOS) The inability to receive a satellite signal because the satellite's orbital path has taken it below the antenna's horizon. This term is relevant to all satellites except geostationary.

low A logic state corresponding to a binary R0S. Satellite imagery is displayed on a computer monitor by a combination of highs and lows. See [high]

low or low-pressure system A horizontal area where the atmospheric pressure is less than it is in adjacent areas. Since air always moves from areas of high pressure to areas of low pressure, air from these adjacent areas of higher pressure will move toward the low pressure area to equalize the pressure. This inflow of air toward the low will be affected by the Earth's rotation (see Coriolis

force) and will cause the air to spiral inward in a counterclockwise direction in the northern hemisphere. The air eventually rises near the center of the low, causing cloudiness and precipitation.

The air in a low rotates in a counterclockwise direction in the Northern Hemisphere, and in a clockwise direction in the Southern Hemisphere. Low-pressure cells are called cyclones.



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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

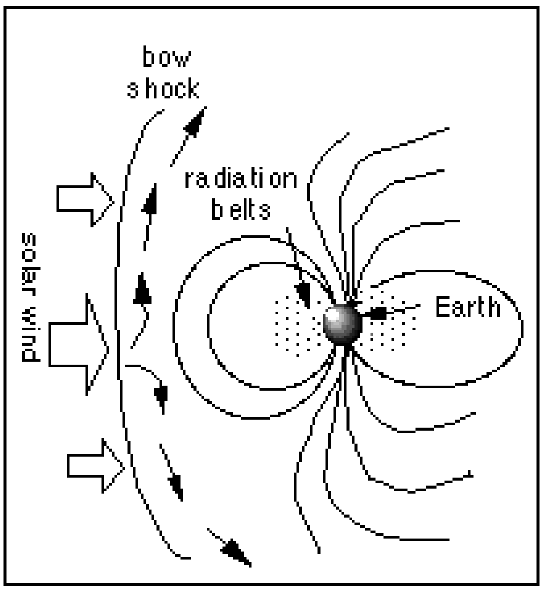
M

- magnetosphere
- MAPS-NET
- MSFC
- mean anomaly
- mean motion
- measurement system integrity
- measurement validation
- Mercator projection
- mesopause
- mesosphere
- metadata
- Meteor
- meteorology
- METEOSAT
- Metsat
- MHz
- micrometer
- microprocessor
- microwave
- middle infrared
- millibar
- Mission to Planet Earth
- model
- modem
- modulation
- monsoon
- Montreal Protocol

- mosaic
- mountain and valley breezes
- MTPE
- Multiplexer
- Multispectral Scanner

magnetosphere The region surrounding a celestial body where its magnetic field controls the motions of charged particles. The Earth's magnetic field is dipolar in nature. That is, it behaves as if produced by a giant bar magnet located near the center of the planet with its north pole tilted several degrees from Earth's geographic north pole.

The Earth's magnetic field presents an obstacle to the solar wind, as a rock in a running stream of water. This obstacle is called a bow shock. The bow shock slows down, heats, and compresses the solar wind, which then flows around the rest of Earth's magnetic field. See Van Allen belts.



MAPS-NET Maryland Pilot Earth Science and Technology Education NETwork. NASA-sponsored education project designed to complement NASA's Mission to Planet Earth. MAPS-NET has been developed to enrich math and science curricula and enhance teacher preparation in Earth system science. Middle and high school teachers learn about Earth sciences and satellite direct readout at graduate-level summer workshops; academia, federal agencies, and the private sector form the support network.

MSFC (Marshall Space Flight Center) See NASA Centers.

mean anomaly (aka M0 or MA or phase) Specifies the mean location (true anomaly specifies the exact location) of a satellite on an orbit ellipse at a particular time, assuming a constant mean motion throughout the orbit. Epoch specifies the particular time at which the satellite's position is defined, while mean anomaly specifies the location of the satellite at epoch. Mean anomaly is measured from 0 degrees to 360 degrees during one revolution. It is defined as 0 degrees at perigee, and hence is 180 degrees at apogee. See *Keplerian elements.*

mean motion (aka N0) The averaged speed of a satellite in a non-circular orbit (i.e., eccentricity>0). see Diagram

mean motion, averaged speed in elliptical orbit

Satellites in circular orbits travel at a constant speed. Satellites in non-circular orbits move faster when closer to the Earth, and slower when farther away. Common practice is to compute the mean motion (average the speed), which is measured in revolutions per day.

measurement system integrity The tracking and documentation over the long term of all causes of error or uncertainty in a final data-analysis product. These include instrument calibration, adequacy of measurement validation, data coverage and sampling density, availability and quality of ancillary data, procedures for data analysis and reduction, the results of checks against independent measurement, and quantitative error analysis.

measurement valication The establishment of confidence in the numerical relationship between the calibrated sensor output and the actual variable being measured.

Mercator projection A method of making maps in which the Earth's surface is shown as a rectangle with the meridians as parallel straight lines spaced at equal intervals and the parallels of latitude as parallel straight lines intersecting the meridians at right angles. Areas away from the equator appear larger than they are, with the greatest distortion near the poles.

mesopause The upper boundary of the mesosphere where the temperature of the atmosphere reaches its lowest point.

mesosphere The atmospheric layer above the stratosphere, extending from about 50 to 85 kilometers altitude. The temperature generally decreases with altitude.

metadata Information describing the content or utility of a data set. For example, the dates on which data were procured are metadata.

Meteor The former Soviet Union's series of polar orbiting weather satellites. The Meteor satellites transmit images in a system compatible with the NOAA polar-orbiting satellites.

meteorology Study of the atmosphere and its phenomena.

METEOSAT (METEOrological SATellite) Europe's geostationary weather satellite, launched by the European Space Agency and now operated by an organization called Eumetsat. METEOSAT transmits at 13691 MHz.

Metsat Generic term for meteorological (weather) satellites.

MHz (megahertz) 10^6 hertz.

micrometer (5m, aka micron) One millionth of a meter, used to measure wavelengths in the electromagnetic spectrum.

microprocessor Controlling unit of a microcomputer, laid out on a tiny silicon chip and containing the logical elements for handling data, performing calculations, carrying out stored instructions, etc.

microwave Electromagnetic radiation with wavelengths between about 1000 micrometers and one meter.

middle infrared Electromagnetic radiation between the near infrared and the thermal infrared, about 2-5 micrometers.

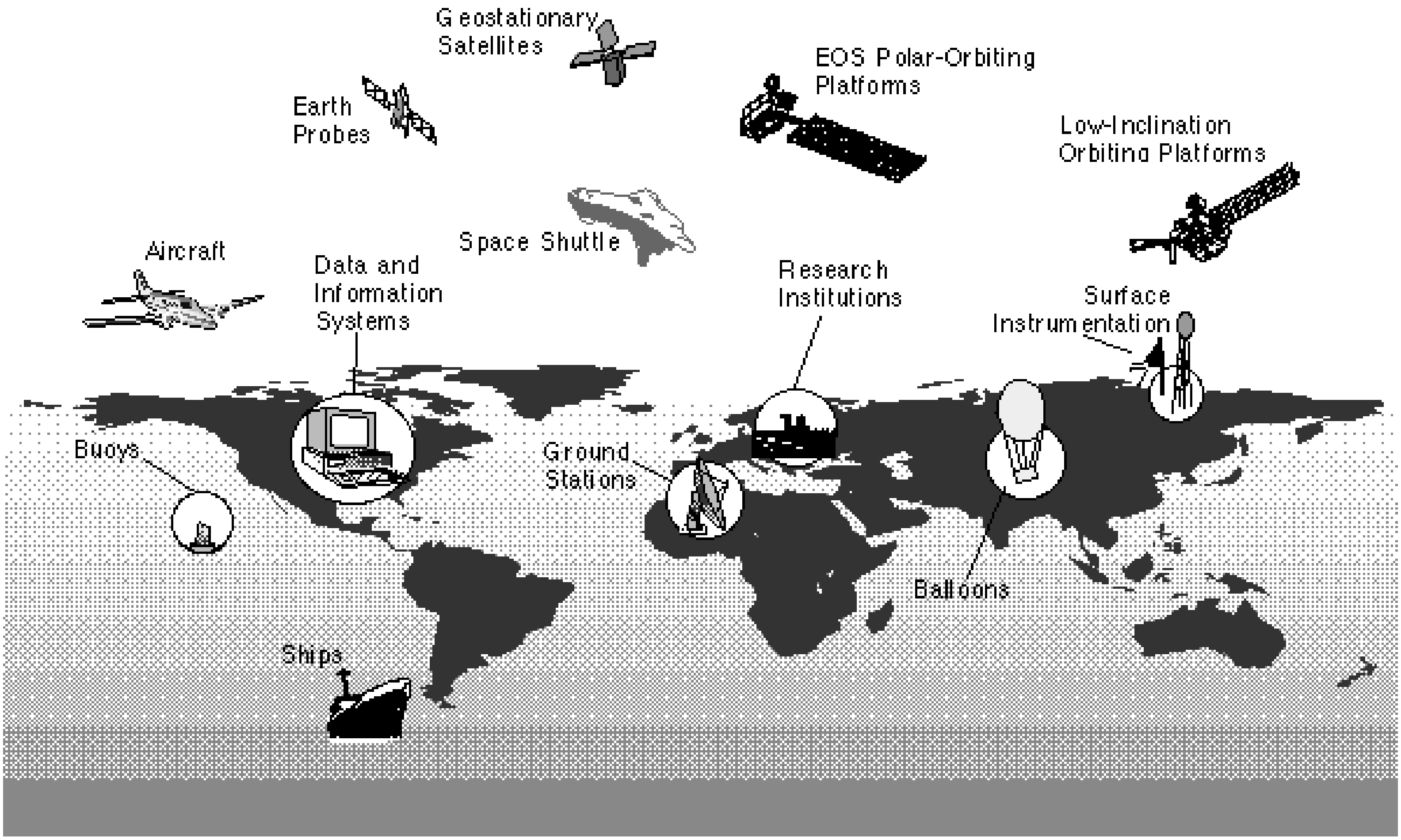
millibar (mb) One thousandth of a bar, a unit of atmospheric pressure. The average atmospheric pressure at sea level is 1.01325 bars or 1013.25 mb. See pascal (Pa), atmospheric pressure.

Mission to Planet Earth (MTPE) International research program to understand our planet's environment as a system. A major challenge of MTPE is to observe, understand, model, assess, and eventually predict global change. Meeting this challenge will help to evaluate the impact that human activity (e.g., clearing forests and burning fossil fuels) has on our environment, and to distinguish human-induced changes from the effects of natural events (e.g. volcanic eruptions, erosion).

NASA's MTPE uses space-, aircraft-, and ground-based measurements to provide the scientific basis for understanding global change. The program will produce long-term global maps of clouds, land cand ocean vegetation, atmospheric ozone, sea-surface temperature, and other global processes necessary to understand the state of the Earth and to detect any patterns of change. This information will be available to scientists and policy makers through the Earth Observing System Data and Information System (EOSDIS).

The centerpiece of NASA's MTPE will be the Earth Observing System (EOS), a series of satellites planned for launch beginning in 1998. Measurements from EOS will be complemented by the Earth Probes, a series of discipline-specific satellites and instruments designed to observe Earth processes where smaller platforms and/or different orbits from EOS are required. Planned Earth Probes will measure tropical rainfall, ocean productivity, ozone, and ocean surface winds.

In addition, MTPE includes current NASA Earth science missions collecting important data on the global environment, such as the Upper Atmosphere Research Satellite (UARS) and the Ocean Topography Experiment (TOPEX/POSEIDON), Space Shuttle experiments such as ATLAS, and aircraft campaigns.



model (noun) A mathematical representation of a process, system, or object developed to understand its behavior or to make predictions. The representation always involves certain simplifications and assumptions.

modem (modulator/demodulator) Device that allows two computers (which use binary data in the form of bits) to communicate using a telephone line (which uses tones). When the computer is transmitting data, the modem is needed to modulate binary data into tones. When receiving data, the device is needed to demodulate the tones to obtain the binary data required by the computer. Since the computer must be both a transmitter and receiver of data, the modem must be able to modulate and demodulate data.

modulation Variation in the frequency of a radio wave in accordance with some other impulse. Modulation is essential to communication systems in which a number of different signals must all share the same medium. One way this sharing can be accomplished is to place each signal in its own band of frequencies in the medium. Amplitude modulation and frequency modulation are two ways in which signals can be moved within the frequency domain to accomplish placement and sharing. The combining of a number of signals to share a communication medium by dividing it into different frequency bands for each signal is called frequency-division multiplexing.

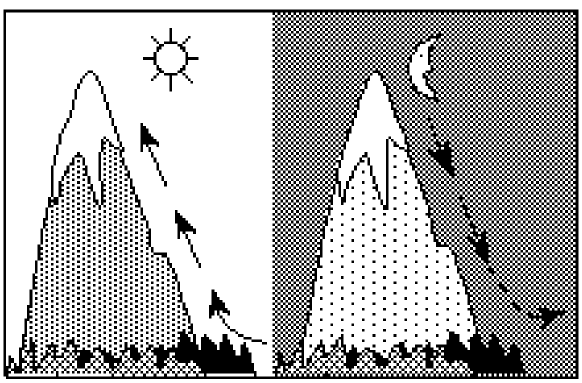
Amplitude modulation (AM) is technologically quite simple, and the bandwidth of the amplitude-modulated carrier is at most twice the bandwidth of the modulating signal. However, an amplitude-modulated carrier is very prone to the effects of additive noise. Frequency modulation (FM) is more complicated than amplitude modulation, and the bandwidth of the frequency-modulated carrier can be many times that of the modulating signal. However, the process of demodulating a frequency-modulated carrier eliminates much of the deleterious effects of additive noise. This trade-off between bandwidth and noise reduction characterizes most communication situations.

monsoon Heavy winds characterized by a pronounced seasonal change in direction. Winds usually blow from land to sea in the winter, while in the summer, the flow reverses and precipitation is more common. Monsoons are most typical in India and southern Asia.

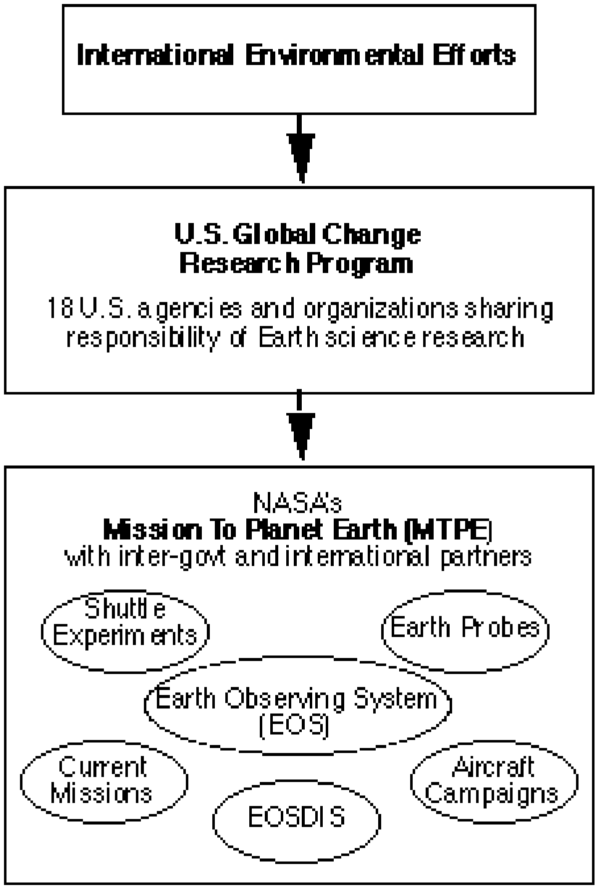
Montreal Protocol An international agreement to drastically reduce CFC production, the Protocol was adopted in Montreal in 1987. It was significantly strengthened at a subsequent meeting in London in 1990 that called for a complete elimination of CFCs by the year 2000. The agreement was again amended by a Meeting of the Parties in Copenhagen in November 1992. Consumption of controlled substances--such as CFCs and halons--was greatly reduced or eliminated, and many accountability dates were moved forward, often from 1 January 2000 to 1 January 1996.

mosaic A composite picture built up from a number of image segments. An example of a mosaic is the WEFAX transmission, which includes both polar and mercator mosaics derived from TIROS-N/NOAA polar orbit image data.

mountain and valley breezes System of winds that blow downhill during the night (mountain breeze) and uphill during the day (valley breeze).



MTPE See Mission to Planet Earth.



multiplexer A device that combines several separate communications signals into one and outputs them on a single line.

Multispectral Scanner (MSS) A line-scanning instrument flown on Landsat satellites that continually scans the Earth in a 185 km. (100 nautical miles) swath. On Landsats 1, 2, 4, and 5, the MSS had four spectral bands in the visible and near-infrared with an IFOV of 80 meters. Landsat-3 had a fifth band in the thermal infrared with an IFOV of 240 meters.

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Looking at Earth From Space

Educational Reference for Teachers--Grades 7-12

Concepts and Terms

N

- nadir
- nano
- nanometer
- NASA
- NASA Centers
- NASA Prediction Bulletins
- NASDA
- National Aeronautics and Space Administration (NASA)
- National Center for Atmospheric Research (NCAR)
- National oceanic and Atmospheric Administration (NOAA)
- National Space Science Data Center (NSSDC)
- National Weather Service (NWS)
- nautical mile
- NCAR
- NCDC
- near infrared
- nephanalysis
- nepheloccygia
- NESDIS
- Newton's law of universal gravitation
- Newton's law of motion
- NGDC
- nibble
- Nimbus Satellite Program
- NOAA
- NODC

- NRA
- NREN
- NSF
- NSFNET
- NSSDC

nadir Point on Earth directly beneath a satellite, the opposite of zenith. Compare with subsatellite point.

nano See International System of Units

nanometer (nm) One billionth of a meter. Nanometers are used to measure wavelengths in the electromagnetic spectrum.

NASA See National Aeronautics and Space Administration

NASA Centers The ten major NASA Centers are:

Ames Research Center (ARC) Located at Moffett Field, California. ARC is active in aeronautical research, life sciences, space science, and technology research. The Center houses the world's largest wind tunnel and the world's most powerful supercomputer system.

The Dryden Flight Research Center, Edwards Air Force Base, California, formerly part of ARC, became a separate entity March 1994. Since the 1940s, this Mojave desert site has been a testing ground for high-performance aircraft and is one of two prime landing sites for the Space Shuttle.

Goddard Space Flight Center (GSFC) Goddard was NASA's first major scientific laboratory devoted entirely to the exploration of space. Located in Greenbelt, Maryland, GSFC's responsibilities include design and construction of new scientific and applications satellites, as well as tracking and communication with existing satellites in orbit. GSFC is the lead center for the *Earth Observing System*, a key element of Mission to Planet Earth. GSFC also directs operations at the Wallops Flight Facility on Wallops Island, Virginia, which each year launches some 50 scientific missions to sub-orbital altitudes on small sounding rockets.

Jet Propulsion Laboratory (JPL) Located in Pasadena, California, JPL is operated under contract to NASA by the California Institute of Technology. Its primary focus is the scientific study of the solar system, including exploration of the planets with automated probes. Most of the lunar and planetary spacecraft of the 1960s and 1970s were developed at JPL. JPL also is the control center for the worldwide Deep Space Network, which tracks all planetary spacecraft.

Lyndon B. Johnson Space Center (JSC) Johnson Space Center, located between Houston and Galveston, Texas, is the lead center for NASA's manned space flight program. JSC has been Mission Control for all piloted space flights since 1965, and now manages the Space Shuttle program. JSC's responsibilities include selecting and training astronauts; designing and testing vehicles and other systems for piloted space flight; and planning and executing space flight missions. The center has a major role in developing the Space Station. In addition, JSC directs operations at the White Sands Test Facility in New Mexico, which conducts Shuttle-related tests. The nearby White Sands Missile Range also serves as a backup landing site for the Space Shuttle.

Kennedy Space Center (KSC) Located near Cape Canaveral, Florida, KSC is NASA's primary launch site. The Center handles the preparation, integration, checkout, and launch of space vehicles and their payloads. All piloted space missions since the Mercury program have been launched from here, including Gemini, Apollo, Skylab, and Space Shuttle flights. KSC is the Shuttle's home port, where orbiters are serviced and outfitted between missions, and then assembled into a complete Shuttle "stack" before launch. The Center also manages the testing and launch of unpiloted space vehicles from an array of launch complexes, and conducts research programs in areas of life sciences related to human spaceflight.

Langley Research Center (LaRC) Oldest of NASA's field centers, LaRC is located in Hampton, Virginia, and focuses primarily on aeronautical research. Established in 1917 by the National Advisory Committee for Aeronautics, the Center currently devotes two-thirds of its programs to aeronautics, and the rest to space. LaRC researchers use more than 40 wind tunnels to study improved aircraft and spacecraft safety, performance, and efficiency.

Lewis Research Center (LeRC) Lewis Research Center, located outside Cleveland, Ohio, conducts a varied program of research in aeronautics and space technology. Aeronautical research includes work on advanced materials and structures for aircraft. Space-related research focuses primarily on power and propulsion. Another significant area of research is in energy and power sources for spacecraft, including the Space Station, for which LeRC is developing the largest space power system ever designed.

George C. Marshall Space Flight Center (MSFC) The MSFC, located in Huntsville, Alabama, is responsible for developing spacecraft hardware and systems, and is perhaps best known for its role in building the Saturn rockets that sent astronauts to the Moon during the Apollo program. It is NASA's primary center for space propulsion systems and plays a key role in the development of payloads to be flown on the shuttle (such as Spacelab). MSFC also manages two other NASA sites: the Michoud Assembly Facility in New Orleans where the Shuttle's external tanks are manufactured, and the Slidell Computer Complex in Slidell, Louisiana, which provides computer support to Michoud and to NASA's John C. Stennis Space Center.

John C. Stennis Space Center (SSC) This Center, located on Mississippi's Gulf Coast, is NASA's prime test facility for large liquid propellant rocket engines and propulsion systems. The main mission of the Center is to support testing, on a regular basis, of the Space Shuttle's main propulsion system. SSC is responsible for a variety of research programs in the environmental sciences and the remote-sensing of Earth resources, weather, and oceans, and is the lead NASA Center for the commer cialization of space remote sensing.

NASA Prediction Bulletins Reports published by NASA's Goddard Space Flight Center providing the latest orbit information on satellites. The report gives information in three parts: 1) two line orbital elements, 2) longitude of the south to north equatorial crossings, and 3) longitude and heights of the satellite crossings for other latitudes.

NASDA See [Japanese National Space Development Agency.]()

National Aeronautics and Space Administration (NASA) U.S. Civilian Space Agency created by Congress. Founded in 1958, NASA belongs to the executive branch of the Federal Government. NASA's mission to plan, direct, and conduct aeronautical and space activities is implemented by NASA Headquarters in Washington, D.C., and by nine major centers spread throughout the United States. Dozens of smaller facilities, from tracking antennas to Space Shuttle landing strips to telescopes are located around the world. The agency administers and maintains these facilities; builds and operates launch pads; trains astronauts; designs aircraft and spacecraft; sends satellites into Earth orbit and beyond; and processes, analyzes, and distributes the resulting data and information. See NASA Centers.

NASA shares responsibility for aviation and space activities with other federal agencies, including the Departments of Commerce, Transportation, and Defense. Much of the work on major projects such as the Space Shuttle and the Space Station is done in the private sector by aerospace companies under government contract.

From its inception, NASA has been directed to pursue the expansion of human knowledge of phenomena in the atmosphere and space. NASA's programs of basic and applied research extend from microscopic sub-atomic particles to galactic astronomy. In addition to enhancing scientific knowledge, thousands of the technologies developed for aerospace have resulted in commercial applications. Science offices at NASA Headquarters carry out a wide range of research activities to fulfill NASA's science goals. Science offices within NASA are:

Office of Mission to Planet Earth (MTPE) focuses on the "home planet" as a dynamic system of land, ocean, atmosphere, and life that can be investigated on a global scale from space using remote-sensing tools. See Mission to Planet Earth.

Office of Life and Microgravity Sciences and Applications explores the basic physics of how solids, liquids, and gases behave in space; seeks an understanding of the basic mechanisms that underlie space adaptation--developing more effective countermeasures to mitigate the physiological effects of space flight; and studies the role of gravity on life.

Office of Space Science includes the Space Physics and Astrophysics Division which studies the entire universe of stars and galaxies, including the sun. The Solar System Exploration division has launched spacecraft to all the known planets except Pluto in its quest to study the solar system.

National Center for Atmospheric Research (NCAR) Non-profit organization dedicated to furthering understanding of the Earth's atmosphere. Located in Boulder, Co., NCAR is operated by the University Corporation for Atmospheric Research (UCAR) and sponsored by the National Science Foundation (NSF).

National Oceanic and Atmospheric Administration (NOAA) NOAA was established in 1970 within the U.S. Department of Commerce to ensure the safety of the general public from atmospheric phenomena and to provide the public with an understanding of the Earth's environment and resources. NOAA includes: the National Ocean Service which charts the oceans and waters of the U.S. and manages 265,000 acres of estuarine reserves; the National Marine Fisheries Service which maintains the world's largest and most complex marine fisheries management system; the NOAA Corps which operates 18 NOAA research and survey ships and flies 15 NOAA aircraft; and the Office of Oceanic and Atmospheric Research which supports experiments, laboratories, and the National Sea Grant College Program, among other efforts. NOAA has two main components: the National Weather Service (NWS), and the National Environmental Satellite, Data, and Information Service (NESDIS).

The National Weather Service provides weather watch and warning services to the public through 57 Weather Service Forecast Offices (WSFO) and over 100 smaller local Weather Service Offices (WSOs) nationwide. Three national forecasting centers provide general and specialized guidance to WSFOs using computer forecast models, satellite data, and conventional surface and upper air observations from around the world. The centers are:

- National Meteorological Center, Camp Springs, Maryland;
- National Severe Storms Forecast Center, Kansas City, Missouri;
- National Hurricane Center, Coral Gables, Florida.

NWS River Forecast Centers (RFCs) provide river stage and flood forecasts.

NESDIS provides support to the Weather Service forecast mission by operating a series of environmental satellites and disseminating satellite imagery and derived products to the National Centers and WSFOs. NESDIS operates three national data and information centers: the National Geophysical Data Center, the National Climatic Data Center (NCDC), and the National Oceanographic Data Center (NODC). See SOCC

NOAA organizations perform numerous services in addition to monitoring weather conditions. They assess crop growth and other agricultural conditions, sense shifting ocean currents, and measure surface temperatures of oceans and land. They relay data from surface instruments that sense tide conditions, Earth tremors, river levels, and precipitation.

National Space Science Data Center (NSSDC) The NSSDC provides on-line and off-line access to a wide variety of astrophysics, space plasma and solar physics, lunar and planetary, and Earth science data from NASA space flight missions, in addition to selected other data, models, and software. Located at Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, the NSSDC is sponsored by the Information Systems Office of NASA's Office of Space Sciences. NSSDC on-line data and services are currently free of charge, off-line support (e.g., replications and mailing of magnetic tapes) are available for the cost of fulfilling the request.

The NSSDC Master Catalog (NMC) provides an on-line listing of available data sets and the forms that the data are available in (such as CD-ROM), and provides information about the spacecraft and experiments (including past, present, and future NASA and non NASA) from which these data were obtained. The on-line NASA Master Directory (NMD) identifies and briefly describes data of potential interest to the NASA research community, and where possible, provides electronic links to publicly accessible data at sites world-wide. On-line information services are made available through the menu-based NSSDC Online Data Information Service (NODIS).

For more information contact:
CRUSO (Coordinated Request & User Support Office) National Space Science Data Center
c/o World Data Center-A-R&S
(only if corresponding from outside the USA) Code 633.4
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771
phone: (301) 286-6695
FAX: (301) 286-1771
Internet: REQUEST@NSSDCA.GSFC.NASA.GOV
DECnet: NSSDCA::REQUEST

National Weather Service (NWS) See National Oceanic and Atmospheric Administration.

nautical mile A unit of distance (U.S.) equal to exactly 1.852 kilometers or about 6076.1 feet. A nautical mile is approximately equal to 1/60 of a degree or 1 minute of arc of a great circle of the Earth (i.e., 1 minute of arc of latitude or of longitude at the equator).

NCAR See National Center for Atmospheric Research.

NCDC National Climatic Data Center, located in Asheville, North Carolina. See National Oceanic and Atmospheric Administration.

near infrared Electromagnetic radiation with wavelengths from just longer than the visible (about 0.7 micrometers) to about two micrometers. See electromagnetic spectrum.

nephanalysis A type of analysis using satellite cloud pictures to study the relationship between cloud forms and storm systems. In classical mythology, Nephele was a woman Zeus formed from a cloud.

nepheloccygia Clouds that resemble recognizable shapes.

NESDIS National Environmental Satellite Data and Information Service. See National Oceanic and Atmospheric Administration.

Newton's law of universal gravitation All bodies attract each other with what is called gravitational attraction. This applies to the largest stars as well as the smallest particles of matter.

The force of attraction between two small bodies (or between two spherical bodies of any size) is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. In other words, the closer two bodies are to each other, the greater their mutual attraction. As a result, to stay in orbit, a satellite needs more speed in a low than a high orbit.

Kepler's three laws of planetary motion, which had been derived empirically by Johannes Kepler, were obtained with mathematical rigor as a consequence of Newton's law of universal gravitation in conjunction with his three laws of motion. See Kepler's three laws of motion.

Newton's laws of motion Newton's three laws of motion are:

1. Every body continues in a state of uniform motion in a straight line unless acted upon by some external force.
2. The time rate of change of momentum (mass x velocity) is proportional to the impressed force. In the usual case where the mass does not change, this law can be expressed in the familiar form: force = mass x acceleration or $F = ma$.
3. To every force or action, there is always an equal and opposite reaction.

Kepler's three laws of planetary motion, which had been derived empirically by Johannes Kepler, were obtained with mathematical rigor as a consequence of Newton's law of universal gravitation in conjunction with his three laws of motion. See Kepler's three laws of motion.

NGDC National Geophysical Data Center, located in Boulder, Colorado. See National Oceanic and Atmospheric Administration.

nibble Four bits of data.

Nimbus Satellite Program A NASA program to develop observation systems meeting the research and development requirements of atmospheric and Earth scientists. The Nimbus satellites, first launched in 1964, carried a number of instruments: microwave radiometers, atmospheric sounders, ozone mappers, the Coastal Zone Color Scanner (CZCS), infrared radiometers, etc. Nimbus-7, the last in the series, provided significant global data on sea-ice coverage, atmospheric temperature, atmospheric chemistry (i.e. ozone distribution), the Earth's radiation budget, and sea-surface temperature. See Total Ozone Mapping Spectrometer (TOMS).

NOAA See National Oceanic and Atmospheric Administration. Operational designation for the U.S. polar-orbiting meteorological satellites. Current NOAA spacecraft are variations of the *TIROS-N* bus.

NODC National Oceanographic Data Center, located in Washington, D.C. See National Oceanic and Atmospheric Administration.

NRA NASA Research Announcement.

NREN National Research and Education Network.

NSF National Science Foundation.

NSFNET National Science Foundation NETwork.

NSSDC See National Space Science Data Center.

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O

oasis A spot in a desert made fertile by water, which normally originates as groundwater.

occluded front (occlusion) A composite of two fronts formed as a cold front overtakes a warm front. A cold occlusion results when the coldest air is behind the cold front. The cold front undercuts the warm front and, at the Earth's surface, coldest air replaces less-cold air.

A warm occlusion occurs when the coldest air lies ahead of the warm front. Because the cold front can not lift the colder air mass, it rides piggyback up on the warm front over the coldest air.

ocean The salt water surrounding the great land masses. The land masses divide the ocean into several distinct portions, each of which also is called an ocean. The oceans include the Pacific Ocean, the Atlantic Ocean, the Indian Ocean, and the Arctic Ocean.

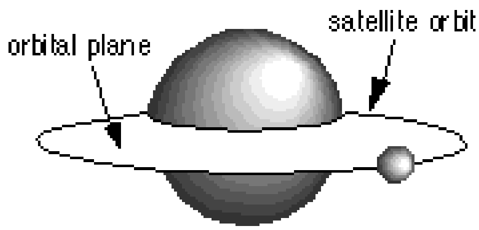
ohm The unit of electrical resistance, equal to the resistance of a circuit in which an electromotive force of one volt maintains a current of one ampere. Named for German physicist Georg S. Ohm (1787-1854).

orbit The path described by a heavenly body in its periodic revolution. Earth satellite orbits with inclinations near 0 degree are called equatorial orbits because the satellite stays nearly over the equator. Orbits with inclinations near 90 degrees are called polar orbits because the satellite crosses over (or nearly over) the north and south poles. See *orbital inclination.*

orbital decay See period decay

orbital inclination See inclination.

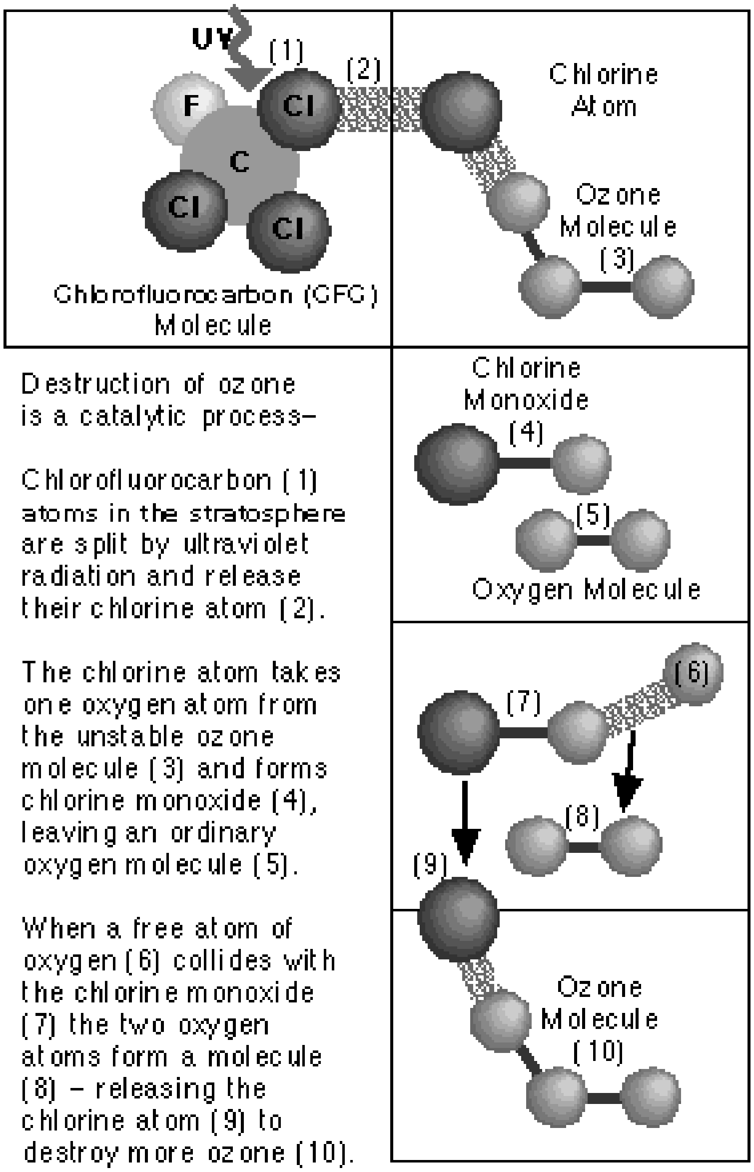
orbital plane An imaginary gigantic flat plate containing an Earth satellite's orbit. The orbital plane passes through the center of the Earth.



ozone An almost colorless, gaseous form of oxygen with an odor similar to weak chlorine. A relatively unstable compound of three atoms of oxygen, ozone constitutes--on the average--less than one part per million (ppm) of the gases in the atmosphere (peak ozone concentration in the stratosphere can get as high as 10 ppm). Yet ozone in the stratosphere absorbs nearly all of the biologically damaging solar ultraviolet radiation before it reaches the Earth's surface where it can cause skin cancer, cataracts, and immune deficiencies, and can harm crops and aquatic ecosystems. See *ozone layer*.

Ozone is produced naturally in the middle and upper stratosphere through dissociation of molecular oxygen by sunlight. In the absence of chemical species produced by human activity, a number of competing chemical reactions among naturally occurring species--primarily atomic oxygen, molecular oxygen, and oxides of hydrogen and nitrogen--maintains the proper ozone balance. In the present-day stratosphere, this natural balance has been altered, particularly by the introduction of man-made chlorofluorocarbons. If the ozone decreases, the ultraviolet radiation at the Earth's surface will increase. See greenhouse gas

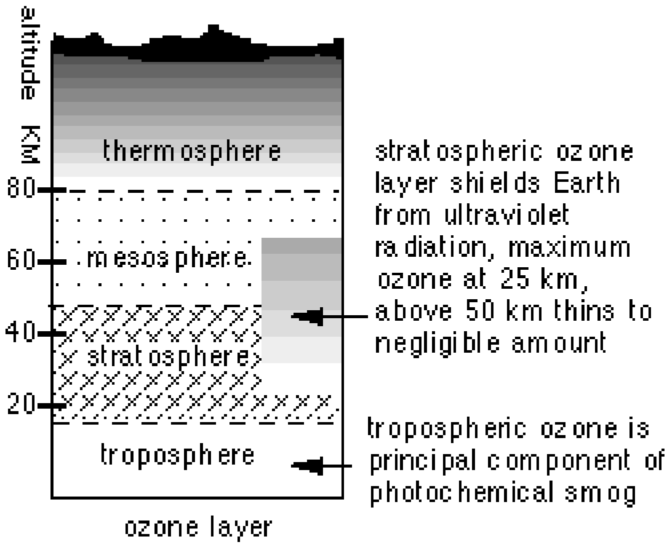
Tropospheric ozone is a by-product of the photochemical (light-induced) processes associated with air pollution. See photochemical smog. Ozone in the troposphere can damage plants and humans.



ozone hole A large area of intense stratospheric ozone depletion over the Antarctic continent that typically occurs annually between late August and early October, and generally ends in mid-November. This severe ozone thinning has increased conspicuously since the late seventies and early eighties. This phenomenon is the result of chemical mechanisms initiated by man-made chlorofluorocarbons (see CFCs). Continued buildup of CFCs is expected to lead to additional ozone loss worldwide.

The thinning is focused in the Antarctic because of particular meteorological conditions there. During Austral spring (September and October in the Southern Hemisphere) a belt of stratospheric winds encircles Antarctica essentially isolating the cold stratospheric air there from the warmer air of the middle latitudes. The frigid air permits the formation of ice clouds that facilitate chemical interactions among nitrogen, hydrogen, and chlorine (elevated from CFCs) atoms, the end product of which is the destruction of ozone.

ozone layer The layer of ozone that begins approximately 15 km above Earth and thins to an almost negligible amount at about 50 km, shields the Earth from harmful ultraviolet radiation from the sun. The highest natural concentration of ozone (approximately 10 parts per million by volume) occurs in the stratosphere at approximately 25 km above Earth. The stratospheric ozone concentration changes throughout the year as stratospheric circulation changes with the seasons. Natural events such as volcanoes and solar flares can produce changes in ozone concentration, but man-made changes are of the greatest concern.



ozone-measuring satellite instruments Satellite-based ozone-measuring instruments can measure ozone by looking at the amount of ultraviolet absorption reflected from the Earth's surface and clouds. Some instruments provide data within the different levels of the atmosphere. The Total Ozone Mapping Spectrometer (TOMS) maps the total amount of ozone between ground and the top of the atmosphere.

The amount and distribution of ozone molecules in the stratosphere varies greatly over the globe, changing in response to natural cycles such as seasons, sun cycles, and winds. Utilizing satellites has enabled scientists to assess ozone levels simultaneously over the entire Earth, and has led them to conclude that global ozone levels are being depleted.

ozone mini-hole(s) Rapid, transient, polar-ozone depletion. These depletions, which take place over a 50-kilometer squared area, are caused by weather patterns in the upper troposphere. The decrease in ozone during a mini-hole event is caused by transport, with no chemical depletion of ozone. However, the cold stratospheric temperatures associated with weather systems can cause clouds to form that can lead to the conversion of chlorine compound from inert to reactive forms. These chlorine compounds can then produce longer-term ozone reductions after the mini-hole has passed.

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Concepts and Terms

P

- paleogeography
- paleoclimate
- panchromatic
- parasitic element
- parity
- pascal
- passive system
- payload
- PC
- perigee
- perihelion
- period
- period decay
- permafrost
- perturbations
- pH
- phase interval
- phenology
- photochemical smog
- photon
- photosynthetically active radiation
- physical climate system
- pixel
- planetary albedo
- plasma
- plate tectonics
- platforms

paleogeography The study of ancient or prehistoric geography.

paleoclimate Climate as it existed in the distant past, particularly before historical records.

panchromatic Sensitive to all or most of the visible spectrum.

parasitic element See antenna.

parity The addition of one or more redundant bits to information to verify its accuracy.

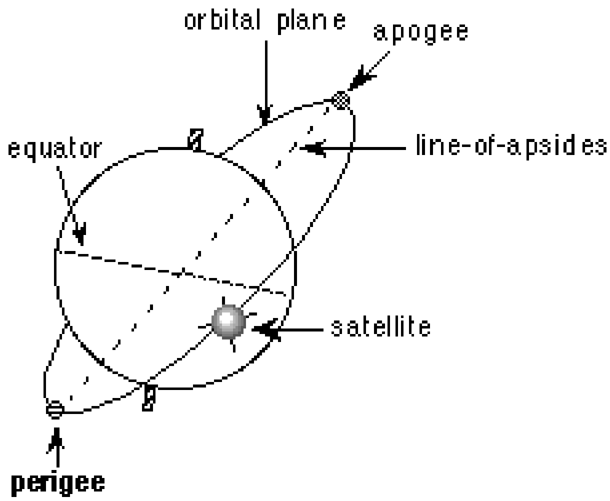
pascal (Pa) Unit of atmospheric pressure named in honor of Blaise Pascal (1632-1662), whose experiments greatly increased knowledge of the atmosphere. A pascal is the force of one newton acting on a surface area of one square meter. It is the unit of pressure designated by the International System. 100,000 Pa = 1000 mb = 1 bar. See atmospheric pressure, millibar.

passive system A system sensing only radiation emitted by the object being viewed or reflected by the object from a source other than the system. See active system.

payload The instruments that are accommodated on a spacecraft.

PC Personal computer.

perigee (aka periapsis or perifocus) On an elliptical orbit path, the point where a satellite is closest to the Earth. See Keplerian elements.



perihelion The point in the orbit of a planet or comet which is nearest the Sun (as opposed to the aphelion, which is the point in the orbit farthest from the Sun).

period Time required for a satellite to make one complete orbit.

period decay (aka decay) The tendency of a satellite to lose orbital velocity due to the influence of atmospheric drag and gravitational forces. A decaying object eventually impacts the surface of the Earth or burns up in the atmosphere. This parameter directly affects the satellite's mean motion.

permafrost See cryosphere.

perturbations Minor corrections to the Keplerian model of a satellite orbit as an ellipse of constant shape and orientation. Since satellite orbits are affected by Earth's gravity and drag caused by the Earth's atmosphere (causing satellites to spiral downward), minor adjustments must be made to the orbit.

pH A symbol for the degree of acidity or alkalinity of a solution. Expressed as a negative logarithm of the hydrogen ion concentration in a solution, $pH = -\log_{10}[H+]$. If the hydrogen ion concentration of a solution increases, the pH will decrease, and vice versa. The value for pure distilled water is regarded as neutral, pH values from 0 to 7 indicate acidity, and from 7 to 14 indicate alkalinity.

phase interval In direct readout, the time between the end of a satellite image start tone and the start of the actual frame data. The phase interval represents white level video, interrupted by a black level pulse marking the start of each line and is used to set up phasing prior to image display.

phenology Subdiscipline of agriculture, a science that treats relations between climate and periodic biological phenomena that are related to or caused by climatic conditions, such as the budding of trees and the migration of birds.

photochemical smog A type of smog that forms in large cities when chemical reactions take place in the presence of sunlight, its principal component is ozone. Ozone and other oxidants are not emitted into the air directly but form from reactions involving nitrogen oxides and hydrocarbons. Because of its smog-making ability, ozone in the lower atmosphere (troposphere) is often referred to as "bad" ozone.

photon A quantum (smallest unit in which waves may be emitted or absorbed) of light.

photosynthetically active radiation Electromagnetic radiation in the part of the spectrum used by plants for photosynthesis.

physical climate system The system of processes that regulate climate, including atmospheric and ocean circulation, evaporation, and precipitation.

pixel The smallest part (smallest addressable element) of an electronically-coded image, such as a computer display. Pixel is a contraction of "picture element."

planetary albedo The fraction of incident solar radiation that is reflected by a planet and returned to space. The planetary albedo of the Earth-atmosphere system is approximately 30 percent, most of which is due to backscatter from clouds in the atmosphere.

plasma A fourth state of matter (in addition to solid, liquid, and gas) that exists in space. In this state, atoms are positively charged and share space with free negatively charged electrons. Plasma can conduct electricity and interact strongly with electric and magnetic fields. The solar wind is actually hot plasma blowing from the sun. See magnetosphere.

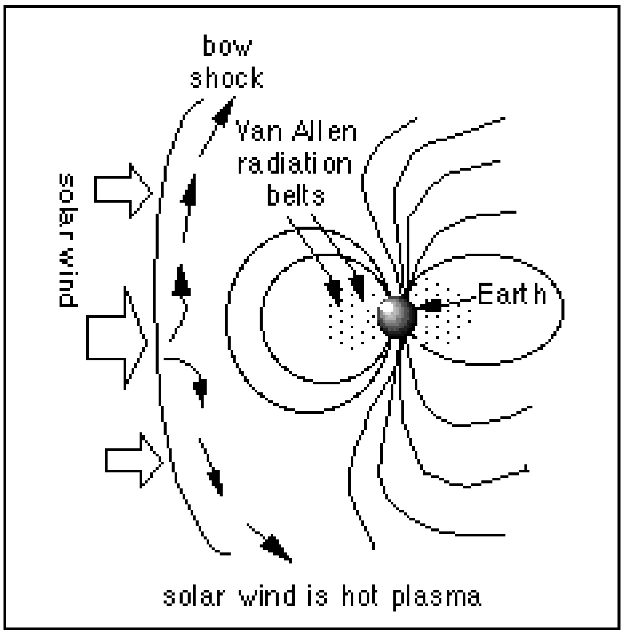
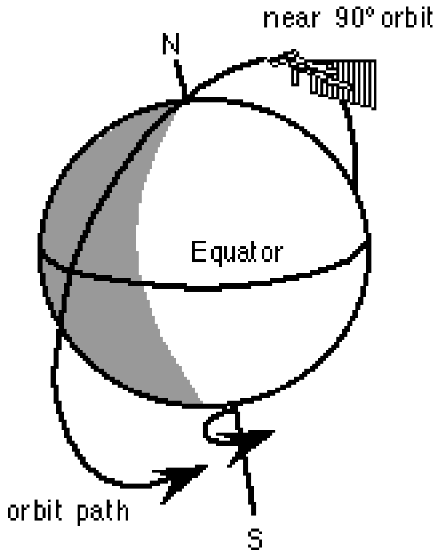


plate tectonics Concept that the Earth's crust is composed of rigid plates that move over a less rigid interior.

platforms A satellite that can carry instruments. See bus. The same term is applied to automatic weather data transmitters installed on buoys, balloons, ships, and planes, and mounted in remote areas.

POES (Polar-orbiting Operational Environmental Satellite) Operated by the National Oceanic and Atmospheric Administration, they are designated "NOAA satellites." Included in this group are the current series of TIROS-N satellites, the third-generation polar-orbiting environmental spacecraft operated by NOAA.

polar orbit An orbit with an orbital inclination of near 90 degrees where the satellite ground track will cross both polar regions once during each orbit. The term is used to describe the near-polar orbits of spacecraft such as the USA's NOAA/TIROS and Landsat satellites.



precession The comparatively slow torquing of the orbital planes of all satellites with respect to the Earth's axis, due to the bulge of the Earth at the equator which distorts the Earth's gravitational field. Precession is manifest by the slow rotation of the line of nodes of the orbit (westward for inclinations less than 90 degrees and eastward for inclinations greater than 90 degrees).

precipitation Moisture that falls from clouds. Although clouds appear to float in the sky, they are always falling, their water droplets slowly being pulled down by gravity. Because their water droplets are so small and light, it can take 21 days to fall 1,000 feet and wind currents can easily interrupt their descent. Liquid water falls as rain or drizzle. All raindrops form around particles of salt or dust. (Some of this dust comes from tiny meteorites and even the tails of comets.) Water or ice droplets stick to these particles, then the drops attract more water and continue getting bigger until they are large enough to fall out of the cloud. Drizzle drops are smaller than raindrops. In many clouds, raindrops actually begin as tiny ice crystals that form when part or all of a cloud is below freezing. As the ice crystals fall inside the cloud, they may collide with water droplets that freeze onto them. The ice crystals continue to grow larger, until large enough to fall from the cloud. They pass through warm air, melt, and fall as raindrops.

When ice crystals move within a very cold cloud (10 degrees F and -40 degrees F) and enough water droplets freeze onto the ice crystals, snow will fall from the cloud. If the surface temperature is colder than 32 degrees F, the flakes will land as snow.

Precipitation Weights:

one raindrop .000008 lbs

one snowflake .0000003 lbs

one cumulus cloud 10,000,000 lbs

one thunderstorm 10,000,000,000 lbs

one hurricane 10,000,000,000,000 lbs

prevailing westerlies Winds in the middle latitudes (approximately 30 degrees to 60 degrees) that generally blow from west to east. The subtropical high pressure regions at the horse latitudes (30 degrees) forces surface air poleward, and the rotation of the Earth causes these winds to bear to the right (east) in the Northern Hemisphere and to the left (east) in the Southern Hemisphere (see Coriolis force). This is, to some extent, an idealized picture of the atmospheric circulation. The actual circulation on individual days includes modifications and variations due to the migratory cyclones and anticyclones of middle latitudes, causing rapid and often violent weather changes, as warm semi-tropical air from the horse latitudes meets cold polar air from the high latitudes. See wind.

prime meridian An imaginary line running from north to south through Greenwich, England, used as the reference point for longitude.

printed circuit A fiber card on which integrated circuits and other electronic components can be mounted. Connections between the components are etched in the correct circuit patterns.

process An association of phenomena governed by physical, chemical, or biological laws. An example of a process is the vertical mixing of ocean waters in the so-called surface-mixed layer; the state variables for this process include temperature, salinity in the water on a vertical scale of tens of meters, and heat flow and wind stress at the sea surface. Other examples include the volcanic deposition of dust and gases into the atmosphere, eddy formation in the atmosphere and oceans, and soil development.

process study An organized, systematic investigation of a particular process designed to identify all of the state variables involved and to establish the relationships among them. Process studies yield numerical algorithms that connect the state variables and determine their rates of change; such algorithms are essential ingredients of Earth system models.

prograde orbit Orbits of the Earth in the same direction as the rotation of the Earth (west-to-east).

psychrometer An instrument designed to measure dew point and relative humidity, consisting of two thermometers (one dry bulb and one wet bulb). The dew point and humidity levels are determined by drying the wet bulb (either by fanning or whirling the instrument) and comparing the difference between the wet and dry bulbs with preexisting calculations. See hygrometer.

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R

R&D Research and Development.

radiant 1. In optics, the point or object from which light proceeds. 2. In geometry, a straight line proceeding from a given point, or fixed pole, about which it is conceived to revolve. 3. In astronomy, the point in the heavens from which a shower of meteors seems to proceed.

radiation Energy transfer in the form of electromagnetic waves or particles that release energy when absorbed by an object.

radiation budget A measure of all the inputs and outputs of radiative energy relative to a system, such as Earth. See Earth Radiation Budget Experiment.

radiative cooling Cooling process of the Earth's surface and adjacent air, which occurs when infrared (heat) energy radiates from the surface of the Earth upward through the atmosphere into space. Air near the surface transfers its thermal energy to the nearby ground through conduction, so that radiative cooling lowers the temperature of both the surface and the lowest part of the atmosphere.

radiative transfer Theory dealing with the propagation of electromagnetic radiation through a medium.

radioactive Giving off or capable of giving off radiant energy in the form of particles or rays, as in alpha, beta, and gamma rays.

radiometer An instrument that quantitatively measures electromagnetic radiation. Weather satellites carry radiometers to measure radiation from snow, ice, clouds, bodies of water, the Earth's surface, and the sun.

radio frequency (RF) A frequency that is useful for radio transmission, usually between 10 kHz and 300,000 MHz.

radiosonde A balloon-borne instrument that measures meteorological parameters from the Earth's surface up to 20 miles in the atmosphere. The radiosonde measures temperature, pressure, and humidity, and transmits or "radios" these data back to Earth. Upper air winds also are determined through tracking of the balloon ascent.

Radiosonde observations generally are taken twice a day (0000 and 1200 UTC) around the globe. NOAA's National Weather Service (NWS) operates a network of about 90 radiosonde observing sites in the U.S. and its territories. When the balloons burst, radiosondes return to Earth on a parachute. Approximately 25 percent are recovered and returned to NWS for reconditioning and reuse.

radio spectrum The complete range of frequencies or wave lengths of electromagnetic waves, specifically those used in radio and television.

radio wave An electrical impulse sent through the atmosphere at radio frequency.

rain forest An evergreen woodland of the tropics distinguished by a continuous leaf canopy and an average rainfall of about 100 inches per year. Rain forests play an important role in the global environment. The Earth sustains life because of critical balances and interactions among many factors. Were there not processes at work that limit the effects of other essential processes, Earth would become uninhabitable. Destruction of tropical rain forests reduces the amount of leaf area in the tropics, and consequently the amount of carbon dioxide absorbed, causing increases in levels of carbon dioxide and other atmospheric gases. It is estimated that cutting and burning of tropical forests contributes about 20 percent of the carbon dioxide added to the atmosphere each year. The World Resources Institute and the International Institute for Environment and Development have reported that the worldUs tropical forests are being destroyed at the rate of fifty-four acres per minute, or twenty-eight million acres lost annually. Rain forest destruction also means the loss of a wide spectrum of biological life, erosion of soil, and possible desertification.

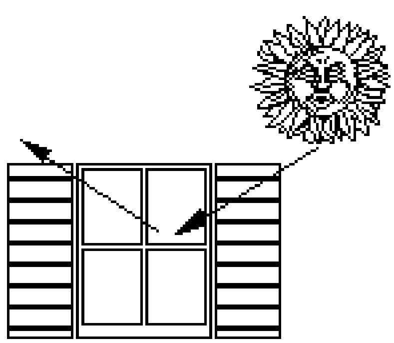
rain gauge Calibrated container that measures the amount of rainfall during a specific period of time.

RAM Random Access Memory. Computers use two types of memory, RAM and ROM. RAM is the computer's working area, the primary location where the microprocessor stores the information it needs. The designation "random access" stems from the microprocessor's ability to access information in memory randomly by knowing its location, or address, rather than hunting through memory sequentially from beginning to end. Because information in RAM is stored electronically, accessing data stored in RAM is much faster than getting that data from a mechanical storage device such as a disk drive. But because it is stored electronically, all information in RAM is temporary (which is why you must store it on a more permanent storage capability, such as a disk). Compare with ROM.

real time As it happens.

receiver sensitivity The ability of a receiver to detect weak signals through the noise level of the receiving system, which includes the antenna and internal thermal noise of the receiver. See signal-to-noise ratio.

reflection The return of light or sound waves from a surface. If a reflecting surface is plane, the angle of reflection of a light ray is the same as the angle of incidence.



remapping Flattening the Earth into a standard map projection. When the spherical Earth is photo-graphed by satellites, areas lying near the outer edge of the picture are distorted. Remapping rectifies the distortion.

remote sensing The technology of acquiring data and information about an object or phenomena by a device that is not in physical contact with it. In other words, remote sensing refers to gathering information about the Earth and its environment from a distance, a critical capability of the *Earth Observing System.*

For example, spacecraft in low-Earth orbit pass through the outer thermosphere, enabling direct sampling of chemical species there. These samples have been used extensively to develop an understanding of thermospheric properties. Explorer-17, launched in 1963, was the first satellite to return quantitative measurements of gaseous stratification in the thermosphere. However, the mesosphere and lower layers cannot be probed directly in this way--global observations from space require remote sensing from a spacecraft at an altitude well above the mesopause. The formidable technological challenges of atmospheric remote sensing, many of which are now being overcome, have delayed detailed study of the stratosphere and mesosphere by comparison with thermospheric research advances.

Some remote-sensing systems encountered in everyday life include the human eye and brain, and photographic and video cameras.

resolution A measure of the ability to separate observable quantities. In the case of imagery, it describes the area represented by each pixel of an image. The smaller the area represented by a pixel, the more accurate and detailed the image. APT has a resolution of 4 km, i.e., each pixel represents a square, 4 km on each side. HRPT has a resolution of 1.1 km at nadir (4 km at edge of scan), and WEFAX of 8 km. See resolution cell.

resolution cell The smallest unit of area in an image of discrete elements. The area represented by a pixel.

retrograde orbit An east-to-west orbit of Earth (Earth spins west to east). See prograde orbit.

revolution Process of the Earth circling the sun in its orbit. Revolution determines the seasons, and the length of the year. In addition, differences in seasons occur because of Earth's inclination (tilt on its axis) of about 23.5 degrees as it revolves around the sun. Compare with rotation.

RF See radio frequency.

right ascension of ascending node (aka =, RAAN or RA of Node) One of six Keplerian elements, it indicates the rotation of the orbit plane from some reference point. Two numbers orient an orbital plane in space; inclination is the first, this is the second. After specifying inclination, an infinite number of orbital planes are possible. The intersection of the equatorial plane and the orbital plane (see diagram, line of nodes) must be specified by a location on the equator that fully defines the orbital plane. The line of nodes occurs in two places. However, by convention, only the ascending node (where the satellite crosses the equator going from south to north) is specified. The descending node (where the satellite crosses the equator going from north to south) is not.

Because the Earth spins, conventional latitude and longitude points are not used to separate where the lines of node occur. Instead, an astronomical coordinate system is used, known as the right-ascension/declination coordinate system, which does not spin with the Earth. Right ascension of ascending node is an angle, measured at the center of the Earth, from the vernal equinox to the ascending node. For example, draw a line from the center of the Earth to the point where the satellite crossed the equator (going from south to north). If this line points directly at the vernal equinox, then RAAN = 0 degree.

ROM Read Only Memory. Refers to the computer memory chips that contain information the computer uses (along with system files) throughout the system, including the information it needs to get itself started. Information in ROM is permanent; it doesn't vanish when the power is turned off. Compare with RAM.

rotation Process of the Earth turning on its axis. Rotation determines day and night, and the length of the day. Compare with revolution.

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Concepts and Terms

S

- sampling
- SAR
- SARSAT
- satellite
- satellite dish
- Satellite Operations Control Center
- satellite orbital elements
- satellite positioning
- satellite revolution
- S-Band
- scanner
- scanning radiometer
- scattering
- screaming eagles
- sea breeze
- sea level
- Search and Rescue
- semi-major axis
- sensor
- sensor calibration
- signal
- signal-to-noise ratio
- sine wave
- sink
- Skylab
- SNR

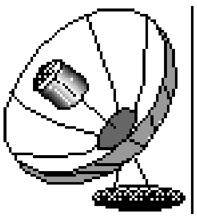
sampling The process of obtaining a sequence of discrete digital values from a continuous sequence of analog data.

SAR See *synthetic aperture radar*.

SARSAT Search and Rescue Tracking System carried on NOAA polar-orbiting satellites that receives emergency signals from persons in distress. The satellites transmit these signals to ground receiving stations in the U.S. and overseas. Signals are forwarded to the nearest rescue coordination center which computes the location from which the emergency signals came and provides the coordinates of the emergency site to a rescue team. See *Search and Rescue.*

satellite A free-flying object that orbits the Earth, another planet, or the sun.

Satellite dish (aka parabolic reflector) Bowl shaped antennas that collect and focus the signals that a satellite beams down to Earth. The dish reflects the incoming radio frequency energy to a focal point where it can be picked up by a feedhorn antenna to transfer the RF energy to a transmission line. The bigger the dish, the greater will be the intercepted RF energy and hence, the gain. For example, a satellite dish is used to receive GOES WEFAX imagery.

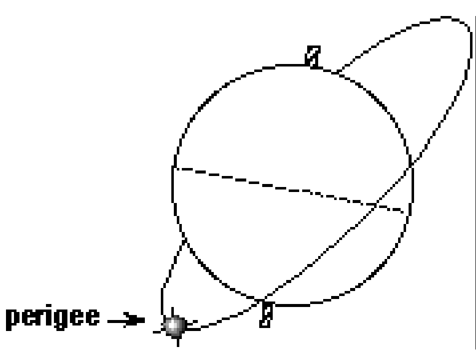


Satellite Operations Control Center (SOCC) NOAA National Environmental Satellite Data and Information Service (NESDIS) Satellite Operations Control Center located in Suitland, Maryland. A principal operating feature of the NOAA system is the centralized remote control of the satellite through command and data acquisition (CDA) stations. The CDA stations transmit command programs to the satellite, and acquire and record meteorological and engineering data from the satellite. Data is transmitted from CDA to Suitland NESDIS Data Processing Services Subsystem (DPSS). DPSS is responsible for data processing and timely generation of meteorological products and distribution of these products.

satellite orbital elements See Keplerian Elements.

satellite positioning A procedure by which satellites are used to locate precise objects or particular points on Earth.

satellite revolution The time from one perigee (the point of an elliptical orbit path where a satellite is closest to Earth) to the next.



S-Band One of the segments or bands into which the radio frequency spectrum above 1000 MHz is divided, designated by letters. Signals from GOES and other geostationary spacecraft transmitting on or near 1691 MHz are transmitting on S-Band.

scanner A system that optically scans its detector(s) across a scene and records or stores the data in a two-dimensional format to form an image.

scanning radiometer An imaging system consisting of lenses, moving mirrors, and solid-state image sensors used to obtain observations of the Earth and its atmosphere. Scanning radiometers, which are the sole imaging systems on all current operational weather satellites, have far better long-term performance than the vidicon TV camera tubes used with earlier spacecraft.

scattering The process by which electromagnetic radiation interacts with and is redirected by the molecules of the atmosphere, ocean, or land surface. The term is frequently applied to the interaction of the atmosphere on sunlight, which causes the sky to appear blue (since light near the blue end of the spectrum is scattered much more than light near the red end).

screaming eagles Cloud pattern so named because some observers maintain they can see the head of an eagle facing west in these cloud patterns. The pattern is similar to a comma, only the pattern is disorganized and not solid. Weather associated with screaming eagles consists of rain showers and gusty surface winds up to about 25 knots. The eagles can intensify and enlarge when moving into areas east of troughs; in that case, intense thunderstorms can develop. Screaming eagles are common in the Pacific Ocean between Hawaii and the equator, and are uncommon in the western Atlantic.

sea breeze Local coastal wind that blows from the ocean to land. Sea breezes usually occur during the day, because the heating differences of land and sea cause pressure differences. Cooler, heavier air from the sea moves in to replace rising warm air on the coastline. See land breeze

sea level The datum against which land elevation and sea depth are measured. Mean sea level is the average of high and low tides.

Search and Rescue International satellite-aided search and rescue project. COSPAS/SARSAT satellites monitor the entire surface of the Earth, and transmit distress signals to special ground receiving stations. The receiving stations compute the location of the signal, and notify the nearest rescue coordination center. Satellite search has cut recovery time from days to hours, and has aided downed airplanes, capsized boats, and persons in other emergencies.

SEM See *Space Environment Monitor, TIROS.*

semi-major axis (aka a) One of the six Keplerian elements, it indicates the size of an orbit. The semi-major axis is one-half of the longest diameter of an orbital ellipse, e.g., one-half of the distance between the *apogee* and *perigee* of an Earth orbit. (The semi-major axis is related to the orbital period and mean motion by Kepler's third law. See Kepler's three laws of motion.) See Keplerian elements for diagram.

sensor Device that produces an output (usually electrical) in response to stimulus such as incident radiation. Sensors aboard satellites obtain information about features and objects on Earth by detecting radiation reflected or emitted in different bands of the electromagnetic spectrum. Analyzing the transmitted data provides valuable scientific information about Earth.

Weather satellites commonly carry radiometers, which measure radiation from snow, ice, clouds, and bodies of water. Spaceborne radars are used for Earth observations, bouncing radar waves off land and ocean surfaces to study sea-surface conditions, ice thickness, and land surface features. A wind scatterometer is a special type of radar designed to measure ocean surface winds indirectly by bouncing signals off the water and measuring them from various angles. Infrared (IR) detectors measure heat generated by Earth features in the IR band of the spectrum.

Photographic reconnaissance sensors in their simplest form are large telescope-camera systems used to view objects on Earth's surface. The bigger the lens, the smaller the object that can be detected. Camera-telescope systems now incorporate all sorts of sophisticated electronics to produce better images, but even these systems need cloudless skies, excellent lighting, and good color contrast between objects and their surroundings to detect objects the size of a basketball. Some of the satellites produce film images that must be returned to Earth, but a more convenient method is to record the image as a series of digital code numbers, then reconstruct the image from the electronic code using a computer at a ground station.

sensor calibration The relationship between input and output for a given measurement.

signal Electrical impulses, sound or picture elements, etc., received or transmitted. Signals can exist in many different forms and media (electrical/wires, acoustic/air, light/transparent fibers, etc.), but all signals will vary with time.

The signal shape plotted as a function of time is called the waveshape or waveform. Some waveforms are repetitive or periodic, that is, a small segment of the waveform repeats itself regularly. Other waveforms, such as noise, are nonperiodic or aperiodic. All waveforms can be distilled into the combination of pure waves called sine waves. The frequency of a sine wave is the rate at which the fundamental shape repeats itself.

Most signals occupy a limited range of frequencies between a lower limit and an upper limit. This range or band of frequencies occupied by a signal is called the bandwidth of the signal.

Communication medium or channel can pass only a specific range or band of frequencies, which is called the bandwidth of the channel. The bandwidths of the channel and the signal determine the number and types of signals that can be transmitted by a particular communication channel. Signals often are too small and need to be made larger through a process called amplification. The amount of amplification is measured in decibels. However, amplification is an imperfect process, and inadvertently introduces various distortions, noise, and bandwidth limitations. Often, multiple signals must share the same medium. One way the sharing can be accomplished is to place each signal in its own band of frequencies within the total band of the medium. The combining of a number of signals to share a medium by dividing it into different frequency bands for each signal is called frequency-division multiplexing.

Frequency-division multiplexing requires the ability to move signals around so that each multiplexed signal occupies its own band. This is accomplished through a process called modulation, in which a high-frequency sine wave carries the signal into the specified band. Either the amplitude or the frequency of the carrier wave can be varied, or modulated, in synchrony with the information-bearing signal. These methods are called amplitude modulation (AM) and frequency modulation (FM). FM is the more complex process of the two, and the bandwidth of the FM carrier can be many times that of the modulating signal.

The process of demodulating a frequency-modulated signal eliminates much of the deleterious effects of additional noise. (The trade-off between bandwidth and noise immunity characterizes most communication systems. Both are analog modulation schemes for multiplexing signals in the frequency spectrum.)

Digitizing a signal requires a number of steps and results in a binary digital signal that takes on one of two discrete values. This process results in considerable immunity to additive noise, but requires a considerable increase in bandwidth.

signal-to-noise ratio (SNR) In decibels (dB), the difference between the amplitude of a desired radio frequency (RF) signal and the internal or external RF noise level in a system. A negative SNR indicates the signal is below the system noise level and unusable. The greater the positive SNR, the less effect noise will have on the final quality. SNR of at least +12dB is necessary to produce imagery with minimal noise effects.

sine wave A smoothly varying wave that repeats itself; its frequency is the rate at which the fundamental shape repeats itself. Any waveform can be distilled into a combination of pure sine waves of varying frequencies and amplitudes.

sink The process of providing storage for a substance. For example, plants--through photosynthesis--transform carbon dioxide in the air into organic matter, which either stays in the plants or is stored in the soils. The plants are a sink for carbon dioxide.

Skylab The first U.S. space station, launched unmanned in May 1973 and soon after occupied in succession by three crews through November 1973.

SNR See *signal-to-noise ratio.*

SOCC See *Satellite Operations Control Center*.

software The programs, data, or routines used by a computer, distinguished from the physical components (e.g., hardware).

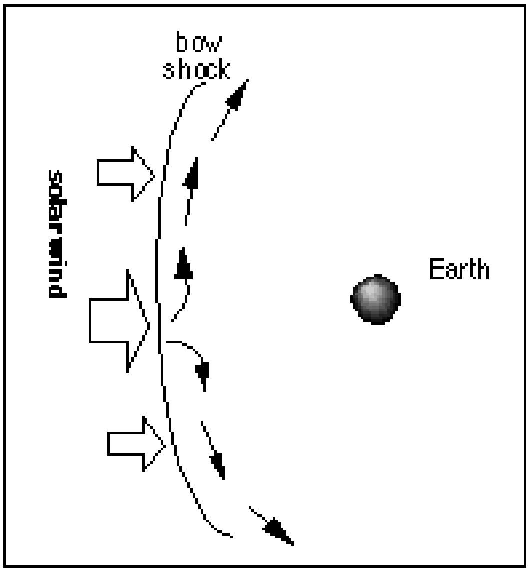
solar backscatter ultraviolet radiometer (SBUV) Instrument that measures the vertical distribution and total ozone in the Earth's atmosphere. Data is used for the continuous monitoring of ozone distribution to estimate long-term trends. SBUV instruments are flown on *NOAA polar-orbiting satellites.*

solar constant Aka total solar irradiance. The constant expressing the amount of solar radiation reaching the Earth from the sun, approximately 1370 watts per square meter. It is not, in fact, truly constant and variations are detectable.

solar cycle Eleven-year cycle of sunspots and solar flares that affects other solar indexes such as the solar output of ultraviolet radiation and the solar wind. The Earth's magnetic field, temperature, and ozone levels are affected by this cycle.

solar radiation Energy received from the sun is solar radiation. The energy comes in many forms, such as visible light (that which we can see with our eyes). Other forms of radiation include radio waves, heat (infrared), ultraviolet waves, and x-rays. These forms are categorized within the electromagnetic spectrum.

solar wind A continuous plasma stream expanding into interplanetary space from the sunUs corona. The solar wind is present continuously in interplanetary space. After escaping from the gravitational field of the sun, this gas flows outward at a typical speed of 400 km per second to distances known to be beyond the orbit of Pluto. Besides affecting Earth's weather, solar activity gives rise to a dramatic visual phenomena in our atmosphere. The streams of charged particles from the Sun interact the Earth's magnetic field like a generator to create current systems with electric potentials of as much as 100,000 volts. Charged electrons are energized by this process, sent along the magnetic field lines towards Earth's upper atmosphere, excite the gases present in the upper atmosphere and cause them to emit light which we call the auroras. The auroras are the northern (aurora borealis) and southern (aurora Australis) lights.



sounder A special kind of radiometer that measures changes in atmospheric temperature with height, as well as the content of various chemical species in the atmosphere at various levels. The High Resolution Infrared Radiation Sounder (HIRS), found on NOAA polar-orbiting satellites, is a passive instrument. See passive system.

Space Environment Monitor (SEM) Instrument that measures the condition of the Earth's magnetic field and the solar activity and radiation around the spacecraft, and transmits these data to a central processing facility. NOAA polar-orbiting and geostationary satellites both carry SEMs. See TIROS.

Spacelab A manned laboratory module built by the European Space Agency (ESA) that accommodates dozens of experiments on each flight, mainly in the categories of materials science and life science.

Spacelink NASA electronic database for educators, with information stored on a computer at the Marshall Space Flight Center. Via computer, educators communicate with NASA education specialists and access the following menus: current NASA news, aeronautics research, U.S. Space Program historical information, aerospace research in the 1980s and beyond, overviews of NASA and its Centers, NASA educational services, classroom materials, and space program spin-offs. The computer access number is 205-895-0028, the data word format is 8 data bits, no parity, and 1 stop bit--300, 1200, or 2400 baud modem required. Callers with Internet access may reach NASA Spacelink at: spacelink.msfc.nasa.gov.

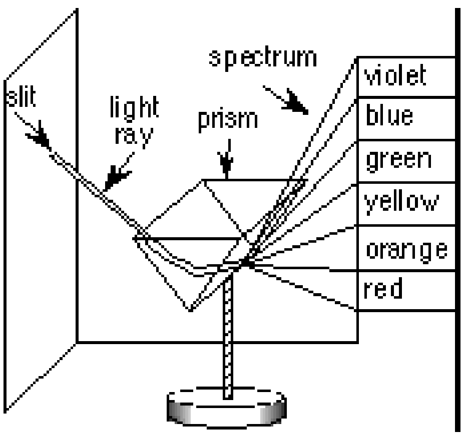
space physics Scientific study of magnetic and electric phenomena that occur in outer space, in the upper atmosphere of the planets, and on the sun.

Space Shuttle NASA's manned, recoverable spacecraft designed to be used as a launch vehicle for Earth-orbiting experiments and as a short-term research platform.

spectral band A finite segment of wavelengths in the electromagnetic spectrum.

spectrum

1. The series of colored bands diffracted and arranged in the order of their respective wave lengths by the passage of white light through a prism or other diffracting medium and shading continuously from red (produced by the longest visible wave) to violet (produced by the shortest visible wave).
2. Any of various arrangements of colored bands or lines, together with invisible components at both ends of the spectrum, similarly formed by light from incandescent gases or other sources of radiant energy, which can be studied by a spectrograph.
3. In radio, the range of wave lengths of radio waves, from 3 centimeters to 30,000 meters, or of frequencies of radio waves, from 10 to 10,000,000 kilocycles. Also radio spectrum.
4. The entire range of radiant energies. See electromagnetic spectrum.



SPOT Systeme Pour l'Observation de la Terre. French, polar-orbiting Earth observation satellite(s) with ground resolution of 10 meters. SPOT images are available commercially and are intended for such purposes as environmental research and monitoring, ecology management, and for use by the media, environmentalists, legislators, etc.

SPOT Image Company that markets data gathered by the SPOT satellite worldwide.

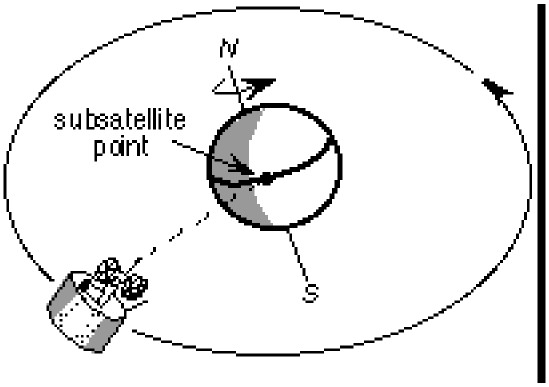
start tone Five seconds of 300 Hz black to white square wave modulation of the WEFAX subcarrier signaling the start of a frame transmission (the beginning of a direct readout image).

stop tone Five seconds of 450 Hz black to white square wave modulation of the WEFAX subcarrier, signaling the stop of a frame transmission (end of a direct readout image).

stratosphere Region of the atmosphere between the troposphere and mesosphere, having a lower boundary of approximately 8 km at the poles to 15 km at the equator and an upper boundary of approximately 50 km. Depending upon latitude and season, the temperature in the lower stratosphere can increase, be isothermal, or even decrease with altitude, but the temperature in the upper stratosphere generally increases with height due to absorption of solar radiation by ozone.

subcarrier The 2400 Hz audio tone transmitted by APT and WEFAX spacecraft. Amplitude modulation of this tone is used to convey video information.

subsatellite point Point where a straight line drawn from a satellite to the center of the Earth intersects the Earth's surface.



subsatellite track See [ground track.]

subsystem

1. A subunit of either the physical climate system (e.g., ocean dynamics) or the biogeochemical cycles (e.g., terrestrial ecosystems).
2. A subunit of a spacecraft, e.g., the telemetry subsystem, the power subsystem, the sensor subsystem, etc.

sun The closest star to Earth (149,599,000 km away on average). The sun dwarfs the other bodies in the solar system, representing approximately 99.86 percent of all the mass in the solar system. One hundred and nine Earths would be required to fit across the Sun's disk, its interior could hold over 1.3 million Earths.

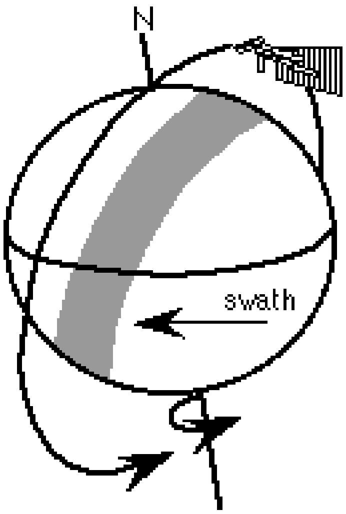
The source of the Sun's energy is the nuclear reactions that occur in its core. There, at temperatures of 15 million degrees Celsius (27 million degrees Fahrenheit) hydrogen atom nuclei, called protons, are fused and become helium atom nuclei. The energy produced through fusion at the core moves outward, first in the form of electrom agnetic radiation called photons. Next, energy moves upward in photon heated solar gas--this type of energy transport is called convection. Convective motions within the solar interior generate magnetic fields that emerge at the surface as sunspots and loops of hot gas called prominences. Most solar energy finally escapes from a thin layer of the Sun's atmosphere called the photosphere--the part of the Sun observable to the naked eye.

The sun appears to have been active for 4.6 billion years and has enough fuel for another 5 billion years or so. At the end of its life, the Sun will start to fuse helium into heavier elements and begin to swell up, ultimately growing so large that it will swallow Earth. After a billion years as a "red giant," it will suddenly collapse into a "white dwarf." It may take a trillion years to cool off completely.

sun-synchronous Describes the orbit of a satellite that provides consistent lighting of the Earth-scan view. The satellite passes the equator and each latitude at the same time each day. For example, a satellite's sun-synchronous orbit might cross the equator twelve times a day, each time at 3:00 p.m. local time. The orbital plane of a sun-synchronous orbit must also precess (rotate) approximately one degree each day, eastward, to keep pace with the Earth's revolution around the sun.

survey mode Refers to observational emphasis upon frequent global coverage, usually with restricted spatial and spectral resolution, aimed at developing a consistent, long-term data product for later interpretation.

swath The area observed by a satellite as it orbits the Earth.



synoptic chart Chart showing meteorological conditions over a region at a given time; weather map.

synoptic view The ability to see large areas at the same time.

synthetic aperture radar (SAR) A high-resolution ground-mapping technique that effectively synthesizes a large receiving antenna by processing the phase of the reflected radar return. The along-track resolution is obtained by timing the radar return (time-gating) as for ordinary radar. The cross-track (azimuthal) resolution is obtained by processing the Doppler phase of the radar return. The cross-track "dimension" of the antenna is a function of the length of time over which the Doppler phase is collected. See Doppler effect.

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T

- Tropospheric Emission Spectrometer
- trough
- true anomaly
- typhoon

TDRSS See Tracking and Data Relay Satellite System.

telemetry

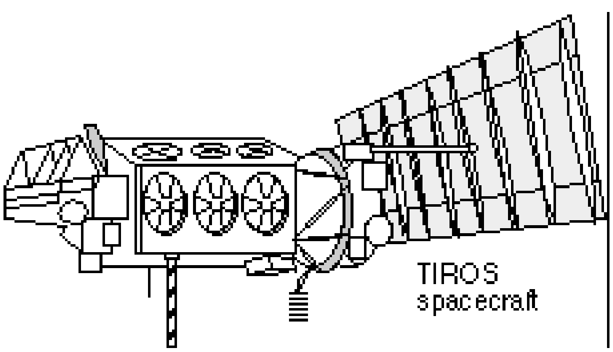
1. Telecommunications transmission to a distance of measured magnitude by radio or telephony with suitably coded modulation, e.g., amplitude, frequency, phase, pulse.
2. Transmission of data collected at a remote location over communications channels to a central station.
3. Surveying measurement of linear distances by use of tellurometer--a device that uses microwaves to measure distance.

telephony Used to transmit sounds between widely removed points with or without connecting wires.

Television and Infrared Observation Satellite Television and Infrared Observation Satellite (TIROS) A series of NASA and NOAA satellites launched to monitor Earth's weather from outer space. The era of the meteorological satellites began with the launch of TIROS-1 on April 1, 1960. For the first time, it was possible to monitor weather conditions over most of the world regularly from space. A series of these satellites were launched throughout the 1960s, those funded by NASA for research and development were called TIROS, and those funded by the Environmental Science Services Administration (ESSA, the predecessor of NOAA) for the operational system were called ESSA.

A second generation of ITOS/NOAA* environmental satellites was initiated by the launch of ITOS-1 in 1970, followed by a number of NOAA satellites. The third generation of TIROS-N/NOAA environmental satellites was initiated by the launch of TIROS-N in 1978.

* Pairs of acronyms such as ITOS/NOAA arise because NASA funds and names its prototype satellites and then the operating agency funds and names the rest of the series.



TIROS-N/NOAA satellites NOAA satellites that continuously orbit the Earth from North to South Pole (hence, polar orbiting) at an altitude of approximately 470 nautical miles (870.44 km or 540.86 statute miles). These environmental satellites collect visible and infrared imagery and provide atmospheric-sounding data and meteorological data relay and collection. A primary mission of TIROS-N/NOAA is to monitor the 70 percent of the globe covered by water-where weather data is sparse and provide continuous data to the National Weather Service for use in numerical forecast modeling. Each TIROS-N/NOAA carries six primary systems:

1. The Advanced Very High Resolution Scanning Radiometer (AVHRR) senses clouds over both ocean and land, using the visible and infrared parts of the spectrum. It stores measurements on tape, and later plays them back to NOAA's command and data acquisition stations. The satellites also broadcast in real time, and the broadcasts can be received around the world by anyone equipped with a direct readout receiving station.
2. The TIROS Operational Vertical Sounder (TOVS) is a 3-part TIROS system to measure:
   - Temperature profile of the Earth's atmosphere from the surface to 10 millibars;
   - Water content of the Earth's atmosphere;
   - Total ozone content of the Earth's atmosphere;
3. The ARGOS Data Collection and Platform Location System **(DCS)** collects data from sensors placed on fixed and moving platforms, including ships, buoys, and weather balloons, and transmits data to a ground station antenna. Because ARGOS also determines the precise location of these moving sensors, it can serve wildlife managers by monitoring and tracking the transmitters placed on birds and animals.
4. The Space Environment Monitor (SEM) measures energetic particles emitted by the sun over essentially the full range of energies and magnetic field variations in the Earth's near-space environment. Readings made by these instruments are invaluable in measuring the sun's radiation activity.
5. Search and Rescue Tracking **(COSPAS/SARSAT)** equipment receives emergency signals from persons in distress. The satellites transmit the signals to ground receiving stations. The signals then are forwarded to rescue coordination centers. The rescue centers compute the location of the signals and provide the coordinates of the emergency site (usually within a few miles).
6. Earth Radiation Budget Experiment (ERBE) is a radiometer, flown on NOAA 9 and 10, designed to measure all radiation striking and leaving the Earth. This enables scientists to measure the loss or gain of terrestrial energy to space. Shifts in this energy "budget" affect the Earth's average temperatures. Even slight changes can affect climatic patterns.

temperature A measure of the energy in a substance. The more heat energy in the substance, the higher the temperature. The Earth receives only one two-billionth of the energy the sun produces. Much of the energy that hits the Earth is reflected back into space. Most of the energy that isn't reflected is absorbed by the Earth's surface. As the surface warms, it also warms the air above it.

terabit A trillion (1012) bits.

thematic mapper (TM) A Landsat multispectral scanner designed to acquire data to categorize the Earth's surface. Particular emphasis was placed on agricultural applications and identification of land use. The scanner continuously scans the surface of the Earth, simultaneously acquiring data in seven spectral channels. Overlaying two or more bands produces a false color image. The ground resolution of the six visible and shortwave bands of the Thematic Mapper is 30 meters, and the resolution of the thermal infrared band is 120 meters. Thematic mappers have been flown on Landsats-4 and -5.

thermal infrared Electromagnetic radiation with wavelengths between about 3 and 25 micrometers.

thunder The sound that results from lightning. Lightning bolts (static electricity) produce intense heat.

This burst of heat makes the air around the bolt expand explosively, producing the sound we hear as thunder. Since light travels faster than sound, we see the lightning before we hear the thunder.

thunderstorm Local storm resulting from warm humid air rising in an unstable environment. Air may start moving upward because of unequal surface heating, the lifting of warm air along a frontal zone, or diverging upper-level winds (these diverging winds draw air up beneath them). The scattered thunderstorms that develop in the summer are called air-mass thunderstorms because they form in warm, maritime tropical air masses away from other weather fronts. More violent severe thunderstorms form in areas with a strong vertical wind shear that forces the updraft into the mature stage, the most intense stage of the thunderstorm. Severe thunderstorms can produce large hail, forceful winds, flash floods, and tornadoes.

TIROS See Television and Infrared Observation Satellite.

TM See thematic mapper.

TNL Thermal Noise Level.

TOGA See Tropical Ocean Global Atmosphere Program.

TOMS See Total Ozone Mapping Spectrometer.

TOPEX/POSEIDON Ocean Topography Experiment, United States (NASA)/France (CNES). Launched in 1992, the mission carries a radar sensor--called an altimeter--to measure the ocean's surface topography with unprecedented precision. TOPEX/POSEIDON is a core element of the international World Ocean Circulation Experiment (WOCE) and the Tropical Ocean Global Atmosphere (TOGA) seagoing measurements program. Mission objectives are to:

- Study ocean circulation and its interaction with the atmosphere to understand climate change better;
- Improve our knowledge of heat transport in the ocean;
- Model global ocean tides;
- Study the marine gravity field;
- Calculate sea-level variations on both global and local scales.

tornado A twisting, spinning funnel of low pressure air. The most unpredictable weather event, tornadoes are created during powerful thunderstorms. As a column of warm air rises, air rushes in at ground level and begins to spin. If the storm gathers energy, a twisting, spinning funnel develops. Because of the funnel's cloud and rain composition and the dust, soil, and debris it draws up, the funnel appears blackish in color. The most energetic storms result in the funnel touching the ground. In these tornadoes, the roaring winds in the funnel can reach 300 mph, the strongest winds on Earth. Funnels usually travel at 20 to 40 mph, moving toward the northeast. When tornadoes form over lakes or oceans they suck water into the funnel cloud and are called waterspouts.

Total Ozone Mapping Spectrometer (TOMS) Flown on NASA's Nimbus-7 satellite, its primary goal is to continue the high-resolution global mapping of total ozone on a daily basis. The Nimbus-7 launch in 1978 enabled TOMS to begin delivering data in 1979 and continue providing information until 1993. TOMS has mapped the total amount of ozone between the ground and the top of the atmosphere, provided the first maps of the ozone hole, and continues to monitor this phenomenon.

Because of its longevity, TOMS also has obtained information on the more subtle trends in ozone outside the ozone hole region. This results from development of a powerful new calibration technique that removes the instrument measurement drift that developed over the years. With this technique applied to the TOMS 14.5-year data record, a global ozone decrease of 2.69 percent per decade was detected.

To ensure that ozone data will be available through the next decade, NASA will continue the TOMS program using U.S. and foreign launches. In 1991, the former Soviet Union launched a Meteor-3 satellite carrying a TOMS instrument provided by NASA. A third TOMS will be launched onboard a NASA Earth probe satellite in 1994, and the Japanese Advanced Earth Observations Satellite (ADEOS) will carry a fourth TOMS when it launches in 1996.

TOVS TIROS Operational Vertical Sounder. See Television Infrared Operational Satellite (TIROS).

Tracking and Data Relay Satellite System Tracking and Data Relay Satellite System (TDRSS) An orbiting communications satellite, developed by NASA, used to relay data from satellite sensors to ground stations and to track the satellites in orbit.

trade winds Surface air from the horse latitudes that moves back toward the equator and is deflected by the Coriolis Force, causing the winds to blow from the Northeast in the Northern Hemisphere and from the Southeast in the Southern Hemisphere. These steady winds are called trade winds because they provided trade ships with an ocean route to the New World. See wind.

TRMM See *Tropical Rainfall Measuring Mission.*

Tropical Ocean-Global Atmosphere (TOGA) TOGA is a program jointly sponsored by the United Nations World Meteorological Organization (WMO); the International Council of Scientific Unions (ICSU); the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Intergovernmental Oceanographic Commission (IOC); and the ICSU Scientific Committee on Oceanic Research (SCOR).

TOGA has four major objectives:

- To collect and catalog observations of the tropical atmosphere and ocean;
- To assess the evolution of the tropical atmosphere/ocean system in real time; To promote the development of short-term climate-prediction computer models for the tropics;
- To study the influence of the tropical atmosphere/ocean system on the climate at higher latitudes.

Tropical Rainfall Measuring Mission (TRMM) A joint NASA/NASDA mission planned for launch in 1997. The goal of TRMM is to obtain a minimum of 3 years of climatologically significant observations of rainfall in the tropics. Because rainfall is such a variable phenomenon, adequate sampling is a difficult problem. By averaging the instantaneous rainfall rates for 30 days over a 5 degrees by 5 degrees grid, TRMM will obtain observations that meet climatological requirements. TRMM measurements, used together with cloud models, also will provide accurate estimates of vertical distributions of latent heating in the atmosphere.

The present uncertainty about the quantity and distribution of precipitation, especially in the tropics, prohibits definition of the mass and energy exchange between the tropical ocean and atmosphere. Since the tropical atmosphere and oceans are closely coupled, cloud radiation and rainfall are likely to have significant effects on ocean circulation and marine biomass.

TRMM data will play a significant role in global change studies, especially in developing an interdisciplinary understanding of atmospheric circulation, ocean-atmospheric coupling, and tropical biology. TRMM data on tropical clouds, evaporation, and heat transfer will be used to understand the larger scale coupling of the atmosphere to oceans. See Earth Probes.

tropical storm formation Tropical storms generally form in the eastern portion of tropical oceans and track westward. Hurricanes, typhoons, and willy-willies all start out as weak low pressure areas that form over warm tropical waters (e.g., surface water temperature of at least 80 degrees F). Initially, winds and cloud formations over the warm tropical waters are minimal. Both intensify with time. Formation of tropical storms also requires a significant Coriolis effect to induce proper spin in the wind formation. As the storm begins to organize itself into a coherent pattern, it will experience increased activity and intensity.

When a storm develops a clearly recognizable pattern, it is referred to as a tropical depression. When wind speeds reach 35 knots (40.3 mph), it is called a tropical storm and is given a name. When wind speed equals or exceeds 74 mph, the storm is called a hurricane. In the western Pacific, a hurricane is referred to as a typhoon. In waters around Australia it is called a cyclone or willy-willy.

Hurricanes intensify when moving over areas of increased water temperatures, and weaken over colder water surfaces. Upper atmosphere wind shear (different wind direction and speeds at different elevations) will frequently prevent or slow intensification of tropical storms by "spreading out" the storm horizontally and preventing the formation of strong updrafts of warm, humid air. Movement over a land-mass will weaken hurricane winds but will result in large-scale rain that can result in large-scale flooding. When encountering a strong frontal system (such as a polar front) the hurricane will curve and track along the leading edge of the front or become implanted in it.

Satellite infrared imagery can identify surface water temperatures that will foster tropical storm development.

tropics The area between 23.5 degrees north and south of the equator. This region has small daily and seasonal changes in temperature, but great seasonal changes in precipitation.

troposphere The lower atmosphere, to a height of 8-15 km above Earth, where temperature generally decreases with altitude, clouds form, precipitation occurs, and convection currents are active. See atmosphere.

Tropospheric Emission Spectrometer A high-resolution infrared spectrometer for monitoring the minor components of the lower atmosphere.

trough Elongated area of low atmospheric pressure, either at the surface or in the upper atmosphere.

true anomaly (aka J) One of six Keplerian elements, it locates a satellite on an orbit. True anomaly is the true angular distance of a satellite (planet) from its perigee (perihelion) as seen from the center of the Earth (sun). See Keplerian elements.

typhoon Hurricanes in the Western Pacific Ocean.

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Concepts and Terms

U

- utraviolet radiation
- UARS
- United States Geological Survey
- United States Global Change Research Program
- Upper Atmosphere Research Satellite
- USGCRP
- UTC
- UV

ultraviolet radiation The energy range just beyond the violet end of the visible spectrum. Although ultraviolet radiation constitutes only about 5 percent of the total energy emitted from the sun, it is the major energy source for the stratosphere and mesosphere, playing a dominant role in both energy balance and chemical composition.

Most ultraviolet radiation is blocked by Earth's atmosphere, but some solar ultraviolet penetrates and aids in plant photosynthesis and helps produce vitamin D in humans. Too much ultraviolet radiation can burn the skin, cause skin cancer and cataracts, and damage vegetation.

UARS See Upper Atmosphere Research Satellite

United States Geological Survey (USGS) A bureau of the Department of the Interior. USGS was established in 1879 following several Federally sponsored independent natural resource surveys of the West and Midwest. The Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The USGS monitors resources such as energy, minerals, water, land, agriculture, and irrigation. The resulting scientific information contributes to environmental-policy decision making and public safety. For example, USGS identifies flood- and landslide-prone areas and maintains maps of the United States.

United States Global Change Research Program (USGCRP) The USGCRP addresses significant uncertainties concerning the natural and human-induced changes to Earth's environment. The USGCRP has a comprehensive and multidisciplinary scientific research agenda. See Global Change Research Program.

Upper Atmosphere Research Satellite (UARS) UARS is part of a long-term, international program of space research into global atmospheric change. Beginning in 1991, NASA's UARS program began to carry out the first systematic, detailed satellite study of the Earth's stratosphere, mesosphere, and lower thermosphere; establish the comprehensive data base needed for an understanding of stratospheric ozone depletion; and bring together scientists and governments around the world to assess the role of human activities in atmospheric change. Launched on September 12, 1991, UARS became the first official space component of Mission to Planet Earth.

USGCRP See United States Global Change Research Program.

UTC See Coordinated Universal Time.

UV Ultraviolet. See ultraviolet radiation.

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Concepts and Terms

V

- Van Allen belts or Van Allen Radiation belts
- vernal equinox
- Very High Frequency
- video
- visible
- Visible/Infrared Spin Scan Radiometer
- volcano
- volt

Van Allen belts or Van Allen Radiation belts Doughnut-shaped regions encircling Earth and containing high energy electrons and ions trapped in the Earth's magnetic field (the magnetic field has definite boundaries, and is distorted into a tear-drop shape by the solar wind). Explorer I, launched by NASA in 1958, discovered this intense radiation zone. These regions are called the inner and outer Van Allen radiation belts, named after the scientist who first observed them. See magnetosphere.

vernal equinox The beginning of spring in the Northern Hemisphere. The time/day that the sun crosses the equatorial plane going from south to north. Very High Frequency (VHF) Referring to the 50-400 MHz portion of the radio frequency spectrum. Polar-orbiting satellite transmissions (APT) are made in the 136-138 MHz range using FM modulation.

video A signal containing information on the brightness levels of different portions of an image along with information on line and frame synchronization. In the case of satellite signals, the video information is transmitted in the form of an AM modulated subcarrier.

visible That part of the electromagnetic spectrum to which the human eye is sensitive, between about 0.4 and 0.7 micrometers. See spectrum.

Visible/Infrared Spin Scan Radiometer (VISSR) High-resolution, multi-spectral imaging system flown on the pre-GOES-8 geostationary GOES spacecraft. Similar systems are flown on the METEOSAT and GMS spacecraft.

volcano A naturally occurring vent or fissure at the EarthUs surface through which erupt molten, solid, and gaseous materials. Volcanic eruptions inject large quantities of dust, gas, and aerosols into the atmosphere. A major component of volcanic clouds is sulfur dioxide, a strong absorber of ultraviolet radiation. Chemical interactions between sulfur dioxide and water cause sulfuric acid aerosols which can scatter some of the incident solar radiation back to space, thus causing a global cooling effect. For example, Mt. Pinatubo in the Philippines erupted in June 1991, and in the following year the global surface temperature was observed to decrease by about 0.3 degrees C.

volt The unit of electromotive force, or difference of potential, which will cause a current of one ampere to flow through a resistance of one ohm. Named for Italian physicist Alessandro Volta (1745-1827).

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Concepts and Terms

W

W Degrees west longitude, referenced to the Greenwich (prime) meridian.

water vapor (aka moisture) Water in a gaseous form.

wave

1. In electricity, a periodic variation of an electric current or voltage.
2. In physics, any of the series of advancing impulses set up by a vibration, pulsation, or disturbance in air or some other medium, as in the transmission of heat, light, sound, etc.

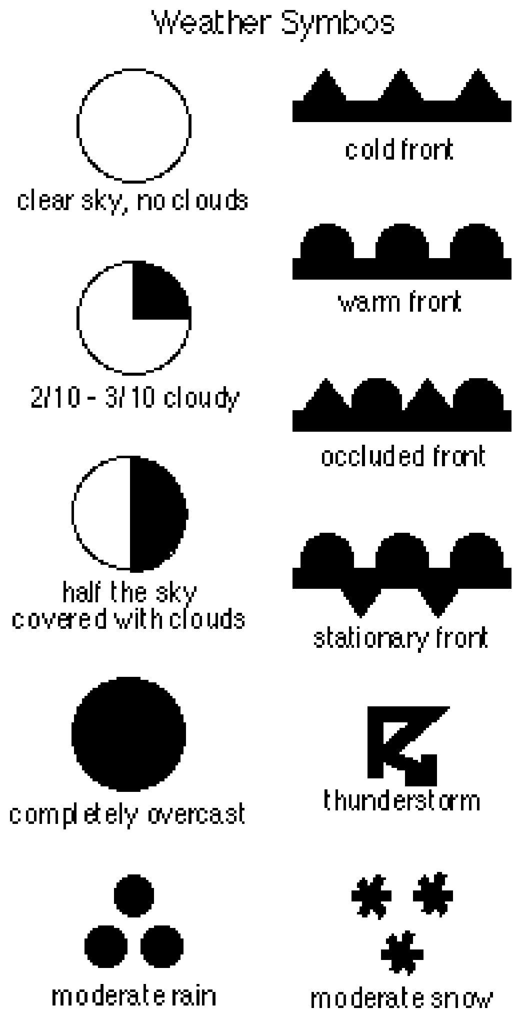
wavelength Physical distance of one period (wave repeat).

weather Atmospheric condition at any given time or place. Compare with climate.

Weather Facsimile (WEFAX) A system for transmitting visual reproductions of weather forecast maps, temperature summaries, cloud analyses, etc. via radio waves. WEFAX transmissions are relayed by NOAA's geostationary GOES spacecraft.

weather symbols Some commonly used symbols are: weather terms:

- **Clear** - Sky cloud-free to 30 percent covered.
- **Sunny** - Sunshine 70-100 percent of the day.
- **Partly sunny and partly cloudy** - Both terms refer to 30 to 70 percent cloud cover. Partly sunny is used in the day; partly cloudy is used at night.
- **Fog** - A cloud on the ground. Fog is composed of billions of tiny water droplets floating in the air.
- **Snow** - Precipitation of ice crystals.
- **Snow flurries** - Intermittent snowfall that may result in little accumulation.
- **Sleet** - Pellets of ice that form when rain or melting snowflakes freeze while falling. (Occurs in cold weather; hail usually occurs in summer.)
- **Freezing rain** - Rain that turns to ice on impact with the surface.
- **Rain** - Extended period of precipitation. Associated with large storm systems rather than single clouds or thunder storms.
- **Showers** - Brief interval of rain that does not affect a large area.
- **Squall** - Fast-moving thunderstorm or line of thunderstorms that often can produce damaging winds, hail, and tornadoes.
- **Hail** - Pieces of ice that fall from thunderstorms. Hail often is composed of concentric rings of ice that form as the particle moves through "wet" and "dry" areas of the thunderstorm.



Weather watch Statement about a particularly dangerous weather system that may occur at some specified time in the future.

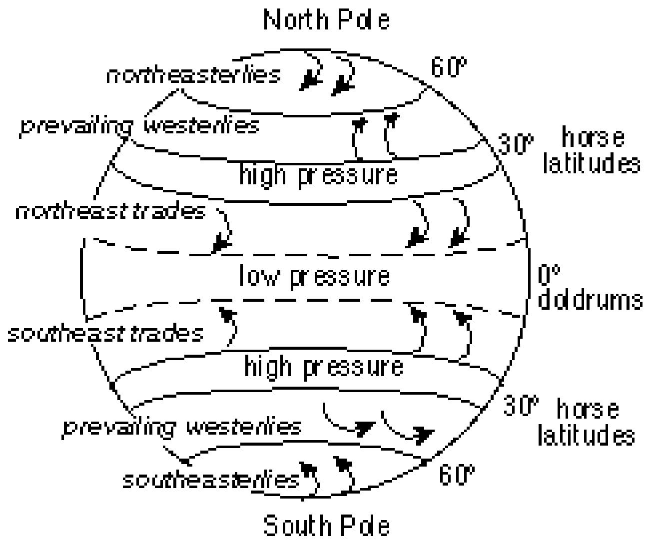
Weather warning Statement that dangerous weather is likely or is occurring. Take action.

WEFAX See weather facsimile.

willy-willy Australian term for tropical cyclone, hurricane.

wind A natural motion of the air, especially a noticeable current of air moving in the atmosphere parallel to the Earth's surface. Winds are caused by unequal heating and cooling of the Earth and atmosphere due to absorbed, incoming solar radiation and infrared radiation lost to space--as modified by such effects as the Coriolis force, the condensation of water vapor, the formation of clouds, the interaction of air masses and frontal systems, friction over land and water, etc.

The preceding chart is an abbreviated version of the Beaufort Wind Scale, named for the British admiral who invented it in 1805.



MPH	*	Description	Effects
0-1	0	calm	smoke rises straight up; water like mirror
1-3	1	light air	smoke drifts slowly; ripples on the water
4-7	2	slight breeze	leaves rustle; small wavelets
8-12	3	gentle breeze	leaves & twigs in motion; large wavelets
13-18	4	moderate breeze	small branches move; small waves 2-4 feet tall
19-24	5	fresh breeze	small trees sway; whitecaps 4-8 feet tall
25-31	6	strong breeze	large branches sway; whitecaps 8-13 feet tall
32-38	7	near gale	whole trees in motion; waves 13 feet tall
39-46	8	gale	twigs break off trees; waves up to 16 feet tall
47-54	9	strong gale	branches break; waves up to 21 feet
55-63	10	whole gale	trees blown over; waves up to 26 feet
64-73	11	storm	widespread damage; waves up to 35 feet tall
74-up	12	hurricane	widespread damage; large ships sink

* Beaufort Number

wind chill The wind can reduce significantly the amount of heat your body retains. The following wind chill chart does not take into account such variables as type of clothing worn, amount of exposed flesh, and physical condition, all of which would alter body heat.

wind speed (mph)	temperature					
	35	30	25	20	15	10
5	32	27	22	16	11	6
10	22	16	10	3	-3	-9
15	16	9	2	-5	-11	-18
20	12	4	-3	-10	-17	-24
25	8	1	-7	-15	-22	-29
30	6	-2	-10	-18	-25	-33
35	4	-4	-12	-20	-27	-35
40	3	-5	-13	-21	-29	-37
45	2	-6	-14	-22	-30	-38

WIND CHILL (degrees F)

wind vane An instrument used to indicate wind direction.

wind vector Arrow representing wind velocity. The arrow points in the direction of the wind. The length of the arrow is proportional to wind speed.

wind velocity Vector term that includes both wind speed and wind direction.

window Term used to denote a region of the electromagnetic spectrum where the atmosphere does not absorb radiation strongly.

WOCE See World Ocean Circulation Experiment.

workstation A "smart" computer terminal that serves as a primary scientific research tool, offering direct access to experimental apparatus, information files, internal computers, and output devices, usually connected to an external communications network.

World Ocean Circulation Experiment (WOCE) A study of the general global circulation of the oceans. It emphasizes the measurements and understanding needed to describe and understand the circulation, to simulate it, and to predict its changes in response to climatic changes.

WWW World Weather Watch.

Y

yagi A type of receiving antenna that has several rod elements mounted on a beam. Its directional pattern of sensitivity and ease of construction make it ideal for APT direct readout stations. See antenna.

Z

zephyr A Mediterranean term for any soft, gentle breeze.

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Educational Reference for Teachers--Grade 7-12

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EOS Acronyms and Abbreviations

To obtain a hard copy of EOS Acronyms/Abbreviations please submit your name and complete mailing address including your phone number to Hannelore Parrish.

A, B, C, D, E, F, G, H, I, J, K L, M, N, O, P, Q, R, S, T, U, V, W, X

2-D	Two-Dimensional
3-D	Three-Dimensional
4-D	Four-Dimensional

Prefixes

n	nano (10-9)
u	micro (10-6)
m	milli (10-3)
c	centi (10-2)
d	deci (10-1)
da	deka (101)
h	hecto (102)
k	kilo (103)
M	mega (106)
G	giga (109)
T	tera (1012)
P	peta (1015)

A

AAOE	Airborne Antarctic Ozone Experiment
AATSR	Advanced Along-Track Scanning Radiometer
ABLE	Atmospheric Boundary Layer Experiment
ACR	Active Cavity Radiometer
ACRIM	Active Cavity Radiometer Irradiance Monitor
ACSYS	Arctic Climate System Study
ADAAC	Affiliated Distributed Active Archive Center
ADALT	Advanced Radar Altimeter
ADC	Affiliated Data Center
ADCLS	Advanced Data Collection and Location System
ADEOS	Advanced Earth Observing Satellite (Japan)
ADPE	Automatic Data Processing Equipment
AE	Atmosphere Explorer
AER	Atmospheric and Environmental Research
AES	Atmospheric Environment Service (Canada)
AFGWC	Air Force Global Weather Central

AGU	American Geophysical Union
AIAA	American Institute of Aeronautics and Astronautics
AIRS	Atmospheric Infrared Sounder
AIS	Airborne Imaging Spectrometer
ALT	Altimeter
ALTA	Active Long Term Archive
AMI	Active Microwave Instrument
AMRIR	Advanced Medium Resolution Imaging Radiometer
AMS	American Meteorological Society
AMSR	Advanced Microwave Scanning Radiometer
AMSU-A	Advanced Microwave Sounding Unit-A
AMTS	Advanced Moisture and Temperature Sounder
AO	Announcement of Opportunity
AOIPS	Atmospheric and Oceanographic Information Processing System
AOL	Airborne Oceanographic Lidar
APAFO	Advanced Particles and Fields Observer
APT	Automatic Picture Transmission
ARC	Ames Research Center
ARGOS+	Argos Data Collection and Location System (France)
ARISTOTELES	Applications and Research Involving Space Technologies Observing the Earth's Field from a Low Earth Orbiting Satellite
ARM	Atmospheric Radiation Measurement Program (DOE)
A-SAR	Advanced Synthetic Aperture Radar
A-SCAT	Advanced Scatterometer
ASF	Alaskan SAR Facility
ASI	Agenzia Spaziale Italiana
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
ATLAS	Atmospheric Laboratory for Applications and Science
ATLID	Atmospheric Lidar
ATMOS	Atmospheric Trace Molecules observed by Spectroscopy
ATS	Applications Technology Satellite
ATSR	Along Track Scanning Radiometer
AURIO	Auroral Imaging Observatory
AVCS	Advanced Vidicon Camera System
AVHRR	Advanced Very High-Resolution Radiometer
AVHRR GAC	AVHRR Global Area Coverage
AVHRR LAC	AVHRR Local Area Coverage
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
AVNIR	Advanced Visible and Near-Infrared Radiometer
AWIPS-90	Advanced Weather Interactive Processing System for the 90's

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B

BAHC	Biosphere Aspects of the Hydrological Cycle Program of the IGBP
BMFT	Bundesministerium für Forschung und Technologie (Germany)
BNSC	British National Space Centre
BOREAS	Boreal Ecosystem - Atmosphere Study
BrO	bromine monoxide

C

C	Celsius, centigrade
Cal/Val	Calibration/Validation
CCD	Charge-Coupled Device
CCRS	Canada Centre for Remote Sensing
CCT	Computer Compatible Tape
CD	Compact Disc
CDCR	Conceptual Design and Cost Review
CDF	Common Data Format
CDOS	Customer Data and Operations System
CD-ROM	Compact Disc - Read Only Memory
CEES	Committee on Earth and Environmental Sciences
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and Earth's Radiant Energy System
CFC-11	CCl_3F, trichlorofluoromethane, Freon-11
CFC-12	CCl_2F_2, dichlorodifluoromethane, Freon-12
CFCs	chlorofluorocarbons
CGCP	Canadian Global Change Program
CH_3	Clmethyl chloride
CH_4	methane
CIESIN	Consortium for International Earth Science Information Networks
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CIT	California Institute of Technology
CLAES	Cryogenic Limb Array Etalon Spectrometer
ClO	chlorine monoxide
$ClONO_2$,$CINO_3$	chlorine nitrate
cm	centimeter
CMS	Configuration Management System
CNES	Centre National d'Etudes Spatiales (France)
CNR	Consiglio Nazionale delle Ricerche (Italy)
CNRS	Centre National de la Recherche Scientifique (France)
CO	carbon monoxide
CO_2	carbon dioxide
Co-I	Co-Investigator
CODMAC	Committee on Data Management, Archiving, and Computation
COSPAR	Committee on Space Research
CRYSYS	Cryospheric System
CSA	Canadian Space Agency
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
CSES	Center for the Study of Earth from Space (Univ of Colorado)
CSU	Colorado State University
CZCS	Coastal Zone Color Scanner

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D

DAAC	Distributed Active Archive Center
DADS	Data Archive and Distribution System

DARA	Deutsche Agentur fur Raumfahrtangelegenheiten (Germany)
DCP	Data Collection Platform
DE	Dynamics Explorer
DEM	Digital Elevation Model
DIAL	Differential Absorption Lidar
DIS	Data and Information System
DLR	Deutsche Forschungsanstalt fur Luft-und Raumfahrt (Germany)
DLS	Dynamic Limb Sounder
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOPLID	Doppler Lidar
DORIS	Determination d'Orbite et Radiopositionement Integre par Satellite
(D)PR	Dual Precipitation Radar
DRS	Data Relay Satellite
DSB	Direct Sounding Broadcast
DSN	Deep Space Network
DWS	Doppler Wind Sensor

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E

E-LIDAR	Experimental Lidar
ECMWF	European Centre for Medium-Range Weather Forecasts
ECS	EOSDIS Core System
EDC	EROS Data Center
EDOS	EOS Data and Operations System
ELV	Expendable Launch Vehicle
EMOC	EOSDIS Mission Operations Center
ENSO	El Niño Southern Oscillation
EOC	EOS Operations Center
EO-ICWG	Earth Observations International Coordination Working Group
EOPM	Electro-Optic Phase Modulation
EOS	Earth Observing System
EOSAT	Earth Observation Satellite Company
EOSDIS	Earth Observing System Data and Information System
EOSP	Earth Observing Scanning Polarimeter
EPA	Environmental Protection Agency
EPOP	European Polar-Orbiting Platform
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
ERL	Environmental Research Laboratory
ERIM	Environmental Research Institute of Michigan
EROS	Earth Resources Observation System
ERS-1	European Remote-Sensing Satellite-1
ERTS-1	Earth Resources Technology Satellite-1
ESA	European Space Agency
ESAD	Earth Science and Applications Division (NASA HQ)
ESMR	Electrically Scanning Microwave Radiometer
ESOC	European Space Operations Center

ESSC	Earth System Sciences Committee
ESTEC	European Space Research and Space Technology Centre
ETM	Enhanced Thematic Mapper (Landsat)
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUV	Extreme Ultraviolet

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F

FCC	Federal Communications Commission
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
Fe	iron
FIFE	First ISLSCP Field Experiment
FIRE	First ISCCP Regional Experiment
FOT	Flight Operations Team
FOV	Field of View
FST	Field Support Terminal
FY	Fiscal Year

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G

g	gram
GAC	Global Area Coverage
GARP	Global Atmospheric Research Program
Gbps	gigabits per second
GCC	Global Change Category
GCDIS	Global Change Data and Information System
GCM	General Circulation Model
GCOS	Global Climate Observing System
GCRP	Global Change Research Program
GCTE	Global Change and Terrestrial Ecosystems Program of the IGBP
GEDEX	Greenhouse Effect Detection Experiment
GEMS	Global Environmental Monitoring System
Geosat	Geodesy Satellite (Navy)
GEWEX	Global Energy and Water cycle Experiment
Gflops	Billions of Floating Point Instructions per Second
GGI	GPS Geoscience Instrument
GGS	Global Geospace Science
GHz	ggahertz
GIMMS	Global Inventory Modeling and Monitoring Study
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GLAS	Geoscience Laser Altimeter System (formerly GLRS-A)
GLI	Global Imager
GLRS-A	Geoscience Laser Ranging System-Altimeter (see GLAS)
GLRS-R	Geoscience Laser Ranging System-Ranger
GMS	Geostationary Meteorological Satellite
GMT	Greenwich Mean Time

GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment
GOMOS	Global Ozone Monitoring by Occultation of Stars
GOMR	Global Ozone Monitoring Radiometer
GOS	Geomagnetic Observing System
GPC	Global Processing Center
GPCP	Global Precipitation Climatology Project
GPS	Global Positioning System
GPSDR	Global Positioning System Demonstration Receiver
GSFC	Goddard Space Flight Center
GTE	Global Tropospheric Experiment
GTCE	Global Tropospheric Chemistry Experiment
GTS	Global Telecommunications System

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H

H_2O	water
H_2O_2	hydrogen peroxide
HALOE	Halogen Occultation Experiment
HAPEX	Hydrological - Atmospheric Pilot Experiment
HBr	hydrogen bromide
HCHO, CH_2O	formaldehyde
HCl	hydrogen chloride
HCMM/AEM-1	Heat Capacity Mapping Mission/Applications Explorer Mission
HCN	hydrogen cyanide
HF	hydrogen fluoride
HIMSS	High-Resolution Microwave Spectrometer Sounder (replaced by MIMR)
HIRDLS	High-Resolution Dynamics Limb Sounder
HIRIS	High Resolution Imaging Spectrometer
HIRS	High Resolution Infrared Radiation Sounder
HIS	High Resolution Interferometer Sounder
HMMR	High-Resolution Multifrequency Microwave Radiometer
HNO_3	nitric acid
HO_x	odd hydrogen (OH, HO_2, H_2O_2)
HOCl	hypochlorous acid
HRDI	High Resolution Doppler Imager
HROI	High Resolution Optical Instrument
HRPT	High Resolution Picture Transmission (e.g., from the AVHRR)
HRV	High Resolution Video (SPOT)
Hz	hertz (cycles per second)

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I

IASI	Improved Atmospheric Sounding Interferometer
IAU	International Astronomical Union
ICC	Instrument Control Center
ICE	International Cometary Explorer
ICF	Instrument Control Facility

ICSU	International Council of Scientific Unions
ICWG	International Coordination Working Group
IDS	Interdisciplinary Science
IEEE	Institute of Electrical and Electronic Engineers
IEOS	International Earth Observing System
IFOV	Instantaneous Field of View
IGAC	International Global Atmospheric Chemistry Program of the IGBP
IGAP	International Global Aerosol Program
IGBP	International Geosphere - Biosphere Programme
II	Interdisciplinary Investigator
ILAS	Improved Limb Atmospheric Spectrometer
IMB	Investigator of Micro-Biosphere
IMG	Interferometric Monitor of Greenhouse Gases
IMS	Information Management System
in	inch
INPA	Instituto Nacional de Pesquisas da Amazonia (Brazil)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
INRA	Institut National de Recherche Agronomiques (France)
INSA	Institut National des Sciences Appliquees (France)
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change
IPEI	Ionospheric Plasma and Electrodynamics Instrument
IPOC	International Partner Operations Center
IR	Infrared
IRIS	Infrared Interferometer Spectrometer
IRTS	Infrared Temperature Sounder
ISAMS	Improved Stratospheric and Mesospheric Sounder
ISAS	Institute of Space and Astronautical Sciences (Japan)
ISCCP	International Satellite Cloud Climatology Project
ISEE	International Sun-Earth Explorer
ISLSCP	International Satellite Land Surface Climatology Project
IST	Instrument Support Terminal
ISTP	International Solar Terrestrial Physics
ISY	International Space Year (1992)
ITIR	Infrared Thermal Imaging Radiometer (renamed ASTER)
IV&V	Independent Verification and Validation
IWG	Investigators Working Group
IWGDMGC	Interagency Working Group on Data Management for Global Change

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J

JEOS	Japanese Earth Observing Satellite
JEM	Japanese Experiment Module
JERS-1	Japanese Earth Remote-sensing Satellite-1
JGOFS	Joint Global Ocean Flux Study Program of the IGBP
JMA	Japan Meteorological Agency
JPL	Jet Propulsion Laboratory
JPOP	Japanese Polar Orbiting Platform
JSC	Johnson Space Center

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K

K	kelvin, unit of thermodynamic temperature (the number of kelvins equals the number of degrees Celsius plus 273.15, i.e., tK=tdegree C +273.15)
kbps	kilobits per second
keV	kilo electron volts
kg	kilogram
kHz	kilohertz
kJ	kilojoule (energy measure)
km	kilometer
kW	kilowatt

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L

LAC	Local Area Coverage
LAGEOS	Laser Geodynamics Satellite
Landsat	Land Remote Sensing Satellite
LANL	Los Alamos National Laboratory
LaRC	Langley Research Center
LAWS	Laser Atmospheric Wind Sounder
LEFI	Local Electric Field Instrument
LERTS	Laboratoire d'Etudes et de Recherches en Teledetection Spatiale (France)
LIDAR	Light Detection and Ranging Instrument
LIDQA	LANDSAT Image Data Quality Analysis
LIMS	Limb Infrared Monitor of the Stratosphere
LIS	Lightning Imaging Sensor
LITE	Lidar In-space Technology Experiment
LR	Laser Retroreflector
LRA	Laser Retroreflector Array
LRPT	Low-resolution Picture Transmission
LWIR	Long-Wavelength (Thermal) Infrared

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M

m	meter
Magsat	Magnetic Field Satellite
MAHLOVS	Middle and High Latitudes Oceanic Variability Study
MAPS	Measurement of Atmospheric Pollution from Satellites
mb	millibar
Mbps	megabits per second
MCC	Mission Control Center
McIDAS	Man-computer Interactive Data Access System
MCP	Meteorological Communications Package, direct broadcast of operational data
MEPED	Medium Energy Proton & Electron Detector
MERIS	Medium Resolution Imaging Spectrometer

MESSR	Multispectral Electronic Self-Scanning Radiometer
METEOR	USSR Operational Weather Satellite
METEOSAT	Geosynchronous Meteorology Satellite (ESA)
MeV	mega electron volts
MF/MAGNOLIA	Magnetic Field Experiment
MHS	Microwave Humidity Sounder
MIMR	Multi-frequency Imaging Microwave Radiometer
MIPAS	Michelson Interferometric Passive Atmosphere Sounder
MISR	Multi-angle Imaging Spectro-Radiometer
MIT	Massachusetts Institute of Technology
MITI	Ministry of International Trade and Industry (Japan)
MLS	Microwave Limb Sounder
mm	millimeter
MOA	Memorandum of Agreement
MODIS	Moderate Resolution Imaging Spectroradiometer
MODIS-N	Moderate Resolution Imaging Spectrometer-Nadir
Modis-T	Moderate Resolution Imaging Spectrometer-Tilt
MOM	Mission Operations Manager
MOPITT	Measurements of Pollution in the Troposphere
MOS-1	Marine Observation Satellite (Japan)
MOU	Memorandum of Understanding
MPE	Mission to Planet Earth
MSFC	Marshall Space Flight Center
MSS	Multispectral Scanner (Landsat)
MSU	Microwave Sounding Unit
MTPE	Mission to Planet Earth
MTS	Microwave Temperature Sounder
MWIR	Medium-Wavelength Infrared

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N

N_2O	nitrous oxide
N_2O_5	nitrogen pentoxide,
nitric	anhydride
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASDA	National Space Development Agency of Japan
NBIOME	Northern Biosphere Observation and Modeling Experiment
NBIS	Northern Biosphere Information System
NCAR	National Center for Atmospheric Research
NCC	Network Control Center
NCDC	National Climatic Data Center
NDSC	Network for the Detection of Stratospheric Change
NDVI	Normalized Difference Vegetation Index
NERC	National Environmental Research Center
NESDIS	National Environmental Satellite, Data, and Information Service
NH_3	ammonia
Nimbus	NASA Meteorological Satellites (1 through 7)
NIR	Near Infrared
NIST	National Institute of Standards & Technology

nm	nanometer
NMC	National Meteorological Center
NO	nitric oxide
NO_2	nitrogen dioxide, nitrogen peroxide
NO_3	nitrate radical
NO_x	nitrogen oxides (NO, NO_2, NO_3)
NO_y	total active nitrogen
NOAA	National Oceanic and Atmospheric Administration
NODS	NASA Ocean Data System
NORDA	Naval Ocean Research and Development Activity
NOSS	National Oceanic Satellite System
NPOP	NASA Polar Orbiting Platform
NRC	National Research Council (Canada)
NRL	Naval Research Laboratory
NSC	Norwegian Space Center
NSCAT	NASA Scatterometer
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSSDC	National Space Science Data Center
NSTS	National Space Transportation System
NWP	numerical weather prediction
NWS	National Weather Service

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O

O_2	(normal) molecular oxygen
O_3	ozone
O_x	odd oxygen (O+O_3)
OClO	chlorine dioxide
OCC	Operations Control Center
OCTS	Japanese Ocean Color Temperature Scanner
OH	hydroxyl radical
OLS	Optical Line Scanner
ONR	Office of Naval Research
OPS	Optical Sensor
OSSA	Office of Space Science and Applications (NASA HQ)
OSTP	Office of Science and Technology Policy
OSU	Oregon State University

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P

PAD	Program Approval Document
PAGES	Past Global Changes
PC	Personal Computer
PEM	Particle Environment Monitor
PGS	Product Generation System
PI	Principal Investigator
PMC	Pressure-Modulator Cell
PMIR	Pressure Modulator Infrared Radiometer

PMR	Pressure Modulator Radiometer
POCC	Payload Operations Control Center
POEM	Polar-Orbiting Earth Mission (ESA)
POEMS	Positron Electron Magnetic Spectrometer
POES	Polar-Orbiting Environmental Satellite
POGO	Polar-Orbiting Geophysical Observatory
POLDER	Polarization and Directionality of Reflectances
POLES	Polar Exchange at the Sea Surface
ppb	parts per billion
ppm	parts per million
PPR	Photopolarimeter Radiometer
ppt	parts per trillion
PR	Precipitation Radar
PRARE	Precise Range and Rate Equipment
PRAREE	Precise Range and Rate Equipment-Extended Version
PRF	Pulse Repetition Frequency
PSC	Polar Stratospheric Cloud
PSO	Project Science Office

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Q

QC	Quality Control

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R

rms	root-mean-square
rpm	revolutions per minute
rss	root-sum-square
RA	Radar Altimeter
Radarsat	Canadian Synthetic Aperture Radar Satellite
RF	Radio Frequency
RIS	Reflector In Space; laser beam absorption, measures O_3, CFCs, etc.

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S

S&R	Search and Rescue
SAFIRE	Spectroscopy of the Atmosphere Using Far Infrared Emission
SAFISY	Space Agency Forum on the International Space Year (1992)
SAGE III	Stratospheric Aerosol and Gas Experiment III
SAM	Stratospheric Aerosol Measurement
SAMS	Stratospheric and Mesopheric Sounder
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Satellite
SBUV	Solar Backscatter Ultraviolet (radiometer)
SCANSCAT	Scanning Scatterometer
SCARABE	Scanning Radiation Budget Experiment
SCATT	Scatterometer

SCF	Scientific Computing Facility
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Charto (sic)
SCOPE	Scientific Committee on Problems of the Environment
SCOR	Scientific Committee for Oceanographic Research
Seasat	Sea Satellite
SeaStar	Spacecraft flying SeaWiFS
SeaWiFS	Sea-viewing Wide Field-of-view Sensors second
SEC	Science Executive Committee of the IWG
SEM	Space Environment Monitor
SERC	Science and Engineering Research Council (UK)
S-GCOS	Space-based Global Change Observation System
SI	Solar Influences
SIO	Scripps Institution of Oceanography
SIR	Spaceborne Imaging Radar
SIR-C	Shuttle Imaging Radar-C
SISEX	Shuttle Imaging Spectrometer Experiment
SLIES	Stratospheric Limb Infrared Emission Spectrometer
SMC	System Management Center
SME	Solar Mesosphere Explorer
SMMR	Scanning Multichannel Microwave Radiometer
SMS/GOES	Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite
SN	Space Network
SNR	Signal-to-Noise Ratio
SO_2	sulfur dioxide
SO_4	sulfate radical
SOCC	Satellite Operation Command and Control
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SPAN	Space Physics Analysis Network
SPARC	Stratospheric Processes and their Role in Climate
SPIE	Society of Photo-Optical Instrumentation Engineers
SPOT	Systeme pour l'Observation de la Terre (France)
SPSO	Science Processing Support Office
SSALT	Solid-State radar Altimeter
SSBUV	Shuttle Solar Backscatter Ultraviolet radiometer
SSM/I	Special Sensor Microwave/Imager
SST	Sea Surface Temperature
STA	Science and Technology Agency (Japan)
STIKSCAT	Stick Scatterometer
SUNY	State University of New York
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
SWIR	Short-Wavelength Infrared
SWIRLS	Stratospheric Wind Infrared Limb Sounder

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T

TAE	Transportable Applications Executive, a computer user interface
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System

TED	Total Energy Detector
TERSE	Tunable Etalon Remote Sounder of Earth
TES	Tropospheric Emission Spectrometer
TGT	TDRSS Ground Terminal
TIR	Thermal Infrared
TIROS	Television and Infrared Observation Satellite
TL	Team Leader
TLCF	Team Leader Computing Facility
TM	Thematic Mapper (Landsat), or Team Member
TMI	TRMM Microwave Imager
TMR	TOPEX Microwave Radiometer
TOGA	Tropical Ocean Global Atmosphere
TOGA/COARE	TOGA/Coupled Ocean-Atmosphere Response Experiment
TOMS	Total Ozone Mapping Spectrometer
TOMUIS	3-D Ozone Mapping with Ultraviolet Imaging Spectrometer
TOPEX/Poseidon	Ocean Topography Experiment (U.S. -France)
TOVS	TIROS Operational Vertical Sounder
TRMM	Tropical Rainfall Measuring Mission (U.S.-Japan)

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U

U.S.	United States
UARS	Upper Atmosphere Research Satellite
UCAR	University Corporation for Atmospheric Research
UCLA	University of California, Los Angeles
UCSB	University of California, Santa Barbara
UHF	Ultra High Frequency
UK	United Kingdom
UNCED	United Nations Conference on Environment and Development (June 3-14, 1992, Rio de Janeiro, Brazil)
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGCRP	U.S. Global Change Research Program
USGS	United States Geological Survey
UTC	Universal Time, Coordinated
UV	Ultraviolet

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V

VAS	VISSR Atmospheric Sounder (GOES)
VHF	Very High Frequency
VIRS	Visible Infrared Scanner
VIRSR	Visible Infrared Scanning Radiometer
VIS	Visible
VISSR	Visible/Infrared Spin-Scan Radiometer (GOES)
VNIR	Visible and Near Infrared

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W

W	watt
WBDCS	Wide-Band Data Collection System
WCRP	World Climate Research Program
WEFAX	Weather Facimile (via geosynchronous weather satellites)
WETNET	Network for Distribution and Joint Analysis of SSM/I Data (MSFC)
WFOV	Wide Field of View
WHOI	Woods Hole Oceanographic Institution
WINDII	Wind Imaging Interferometer
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWW	World Weather Watch

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X

XBT	Expendable Bathythermograph
XIE	X-ray Imaging Experiment
X-SAR	X-band Synthetic Aperture Radar

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